Healthy eating at schools

- How does a school food programme affect the quality of dietary intake at lunch among children aged 7-13 years?

Marianne Sønderby Sabinsky
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DTU Food
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Preface

In the spring 2007, the Minister of Food announced a nationwide project about school food programmes in order to promote healthy eating habits among Danish children and adolescents. Furthermore, the aim was to gain knowledge of implementing a sustainable school food programme paid by the parents.

In the fall 2007, 38 schools received funds from the Danish Food Industry Agency to implement a school food programme with a free period of two months during 2008. Funds were also allocated for evaluation of this project. EVIUS (EffektVurdering af Interventioner omkring frokost for børn og Unge I Skoler) is an interdisciplinary project divided into four work packages, each designed from different perspectives with the purpose to evaluate the school food programme.

This PhD thesis presents the results of the dietary evaluation of the school food programme.

The project was made possible through financial support from the Danish Food Industry Agency, the National Food Institute and Division of Nutrition at the National Food Institute.

Evaluation of health promotion initiatives is important to obtain useful knowledge of effectiveness of different strategies/interventions. Therefore, the economic priority of evaluation of this school food programme was very appropriate. Measuring and assessing dietary intake is an ongoing challenge, especially among pediatric populations. Thus, it is my hope that this PhD thesis may contribute with inspiration, relevant tools and methods for measuring and assessing dietary intake in health promotion interventions and thereby provide credible evidence regarding healthy eating in the school setting.

Marianne Sønderby Sabinsky, August 2013

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I would also like to thank Helle Sommer that performed the statistical analyses in Paper III.

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Special thanks to students, teachers and principals at the 8 schools that have participated in the project. Thank you for the kindness and support we have encountered in our many visits on the schools.

Last but not least I am very grateful to my family and my friends, and especially to my dear husband Claus and to my children Emma, Laura and Mathias for their love, patience and support during this project, and particularly during the last hectic period.

Abbreviations

BMI: Body Mass Index

DLW: Doubly labelled water

DPM: Digital photographic method

E%: Percentage of total energy

g: gram

GIES: General Intake Estimation System

kJ: Kilojoule

Meal IQ: Meal Index of dietary Quality

MJ: Megajoule

NNR 2004: Nordic Nutrition Recommendations 2004

PDL-index: Preschoolers Diet-Lifestyle Index

RC-DQI: Revised Children's Diet Quality Index

SHMI: Simple Healthy Meal Index

YHEI: Youth Healthy Eating Index

List of papers

This PhD thesis is based on the following three papers (paper I, II, III), referred to in the text by their roman numbers and complete versions are included as appendices:

I. Validation of a digital photographic method for assessment of dietary quality of school sandwiches brought from home
Sabinsky MS, Toft U, Andersen KK & Tetens I
Food & Nutrition Research, 2013, **57**(20243), DOI:10.3402/fnr.v57i0.20243

II. Development and validation of a Meal Index of dietary Quality (Meal IQ) to assess the dietary quality of school meals
Sabinsky MS, Toft U, Andersen KK & Tetens I
Public Health Nutrition, 2012, **15**(11), 2091-2099

III. Effect of implementing school meals compared with packed lunches on quality of dietary intake among children aged 7-13 years
Sabinsky MS, Toft U, Sommer HM & Tetens I
Submitted 2013

Summary

Background and aim

In 2007, the Danish Food Industry Agency announced a project where Danish schools could apply for funds to establish a school food programme to provide the school children with free school meals for two months during 2008. This school food programme should be tested and evaluated. The present PhD thesis is based on evaluation of the dietary effect of this project.

There is room for improvement of the dietary habits of Danish children. Dietary habits are influenced by multiple factors across different contexts. The school setting is known as a suitable arena for promotion of healthy eating. In Denmark most children eat a packed lunch brought from home.

It is challenging to collect dietary data from a pediatric population where recall problems exist and estimation of portion sizes can be complicated. Thus, to measure and assess the dietary effect of an intervention, new valid methods are needed.

The overall aim of this PhD thesis was to evaluate the dietary effect of a school food programme in Danish schools on the quality of lunch consumed by children aged 7-13 years compared to packed lunches brought from home. Furthermore, the aim was to develop appropriate methods to measure and assess dietary intake for evaluation of interventions, which are designed to promote credible evidence to this area. The objectives were; to evaluate the validity and reliability of a digital photographic method (DPM) to assess the quality of dietary intake from packed lunches brought from home among children aged 7-13 years (paper I); to develop and validate an index for assessment of dietary quality of school meals, either brought from home or provided by the schools (paper II); to evaluate the effect of implementing a school food programme on the dietary quality of lunches consumed by students aged 7-13 years compared to packed lunches brought from home and furthermore to investigate if a possible effect would differ between the youngest school children and the older (paper III).

Methods

The evaluation of the school food programme was conducted in 4 intervention schools and 4 control schools from all over Denmark. Data on packed lunches were collected at baseline. At 1st follow-up the children in the intervention schools were offered free school meals and at the 2nd follow-up the school meals were paid. The control group had packed lunches at all measurements. Collection of data covered 3 consecutive days during a week at each of the three measurements. In total 984 school children were invited at baseline – 493 from the 2nd -3rd grades and 491 from the 5th-6th grades. A standardized DPM was used to collect data on food intake 3 consecutive days in a week at all of the 3 measurements. To assess the dietary quality of food consumed a Meal Index of dietary Quality (Meal IQ) was developed.

The validity and reliability of the DPM was tested on weighed foods of 191 packed lunches. The Meal IQ was developed and validated against calculated nutrient content of both 191 packed lunches and 63 school meals.

Results

Implementing a school food programme increased the quality of dietary intake among school children aged 7-13 years at 1st follow-up where the school meals were free, compared to the packed lunches brought from home (P=0.004). At the 2nd follow-up, where the school meals were not provided for free, only a limited number of children ate school meals and there was no difference in quality of dietary intake at lunch among children in the intervention and control schools (P=0.343). The statistical analyses demonstrated some differences in changes in dietary quality intake at lunch between school children in the 2nd-3rd grades and 5th-6th grades. This was not due to different effect of the school food programme but was mainly explained by more skipped meals in the oldest age group compared to the youngest age group.

Correlation coefficients and cross-classifications between the DPM and the weighed foods showed good agreement. There were no statistical differences between fish, fat, starch, whole grains and Meal IQ using the two methods. Differences were found for fruit and vegetables. Bland-Altman analyses showed a tendency to underestimate high amounts of these variables using the DPM. For inter-rater reliability, Kappa statistics ranged from 0.59 to 0.82 across the dietary components and Meal IQ.

A higher Meal IQ score was associated with a higher overall dietary quality including lower contents of fat, saturated fat and added sugars, higher contents of fiber, various vitamins and minerals, and more fruit, vegetables and fish.

Conclusion and perspectives

Offering a free school meal had a positive effect on the change in dietary quality of the lunches consumed by school children aged 7-13 years compared to packed lunches brought from home. No effect was measured when the school meals were no longer provided for free. The dietary effect of the school food programme did not depend on age.

The standardized DPM was shown to be valid and reliable for assessment of the dietary quality of packed lunches brought from home. Furthermore the Meal IQ was found to be valid and a useful evaluation tool for assessing the dietary quality of school meals or packed lunches brought from home.

Future research has to refine the methods for dietary assessment. Utilizing the technology for dietary assessment may decrease the burden of the researcher and thereby improve the cost-effectiveness and possibly the accuracy of the DPM. Using the DPM to estimate food intake in free-living conditions among children is also a relevant perspective because data on the entire diet could be achieved.

Furthermore, future research has to focus on development of multicomponent school-based interventions which take into account the multiple factors and environments which affect the dietary habits of children. The focus of such an intervention could be implementation of a sustainable school food programme. Another focus could be improvement of the packed lunches brought from home with the purpose to contribute to the shaping of a healthier dietary behaviour among Danish school children.

Sammendrag (Danish summary)

Baggrund og formål

I 2007 annoncerede fødevareministeren et projekt om skolemad, hvor danske skoler kunne søge midler til etablering af en skolemadsordning med mulighed for at give deres elever gratis skolemad 2 måneder i løbet af 2008. Disse skolemadsordninger skulle afprøves og evalueres. Denne PhD-afhandling er baseret på den ernæringsmæssige evaluering af dette skolemadsprojekt.

Der er mulighed for at forbedre danske børns kostvaner. Kostvaner er under indflydelse af et komplekst samspil mellem forskellige arenaer og faktorer. Skolen er en hensigtsmæssig arena til at fremme sunde kostvaner. I Danmark spiser de fleste skoleelever en medbragt madpakke til frokost.

Det er en udfordring at indsamle kostdata ikke mindst blandt børn, hvilket skyldes recall problemer og vanskeligheder med at estimere portionsstørrelser. Der er således brug for nye valide metoder for at vurdere den ernæringsmæssige effekt af en intervention.

Det overordnede formål med denne PhD-afhandling er at evaluere den ernæringsmæssige effekt af skolemadsordninger på skoleelevers kostindtag til frokost sammenlignet med medbragte madpakker. Endvidere var formålet at udvikle egnede metoder til måling og vurdering af kosten. Delmålene var at vurdere validiteten og reliabiliteten af en digital fotometode anvendt til at vurdere kvaliteten af medbragte madpakker til børn (artikel I), desuden at udvikle og validere et indeks til vurdering af den ernæringsmæssige kvalitet af et måltid skolemad eller en medbragt madpakke (artikel II) og at evaluere effekten af at implementere en skolemadsordning på den ernæringsmæssige kvalitet af den frokost, børn spiser i skolen, og at undersøge om denne effekt er forskellig i hos elever fra indskolingen og mellemtrinet (artikel III).

Metoder

I undersøgelsen indgår 8 skoler fra hele Danmark, hvoraf de 4 er rekrutteret blandt de skoler, der har modtaget tilskud fra Fødevareerhverv til etablering af en skolemadsordning og derudover 4 matchende kontrolskoler. I alt har 984 elever deltaget i undersøgelsen, 493 elever fra 2. og 3. klasse og 491 elever fra 5. og 6. klasse. Der er indsamlet data ved baseline, hvor eleverne spiste deres medbragte madpakker, ved 1. follow-up, hvor eleverne på interventionsskolerne fik gratis skolemad og ved 2. follow-up, hvor skolemadsordningen var videreført, men som en forældrebetalt ordning. Kostdata er indsamlet ved anvendelse af en standardiseret digital fotometode. Den ernæringsmæssige kvalitet af elevernes frokost er vurderet ud fra billeder af elevernes måltider ved anvendelse af et dertil udviklet kostkvalitetsindeks for måltider (Meal IQ).

Validiteten og reliabiliteten af den digitale fotometode blev testet på vejede kostregistreringer for 191 madpakker. Det udviklede kostkvalitetsindeks (Meal IQ) blev valideret op imod næringsstofberegninger af 191 madpakker og 63 måltider skolemad.

Resultater

Implementeringen af skolemadsordningerne havde ved 1. follow-up, hvor skolemaden var gratis, ført til en øget ernæringsmæssig kvalitet af den frokost, der blev spist blandt elever i alderen 7-13 år sammenlignet med kontrolgruppen, der fik madpakker (P=0.004). Ved 2. follow-up, hvor skolemaden ikke længere var gratis, var det kun et begrænset antal børn, der spiste skolemad, og ved denne måling var der ikke forskel på den ernæringsmæssige kvalitet af den frokost, der blev spist blandt børn på interventions- og kontrolskolerne (P=0.343). De statistiske analyser viste nogle forskelle i den ernæringsmæssige kvalitet af den spiste frokost mellem elever i 2.-3. klasse og 5.-6. klasse. Disse forskelle skyldtes ikke en forskellig ernæringsmæssig effekt af skolemadsordningerne, men kunne derimod hovedsageligt forklares ud fra, at flere elever i 5.-6. klasse ikke spiste frokost sammenlignet med elever i 2.-3. klasse.

Korrelationskoefficienter og kryds-klassificeringer viste god overensstemmelse mellem den digitale fotometode og de vejede kostregistreringer. Der var ingen statistisk forskel på fisk, fedt, kulhydrat, fuldkorn og Meal IQ mellem de to metoder. Forskelle blev derimod fundet for frugt og grønt. Bland-Altman analyser viste en tendens til at underestimere høje mængder af disse variable ved brug af den digitale fotometode. Reliabiliteten mellem målere viste Kappa-værdier mellem 0.59 og 0.82 for de forskellige komponenter i Meal IQ og den totale Meal IQ score.

En højere Meal IQ score var associeret med en højere overordnet ernæringsmæssig kvalitet, herunder et lavere indhold af fedt, mættet fedt og tilsat sukker samt højere indhold af fiber, forskellige vitaminer og mineraler samt frugt, grøntsager og fisk.

Konklusion og perspektiver

Den gratis skolemadsordning har en positiv effekt på den ernæringsmæssige kvalitet af det kostindtag, elever indtager til frokost sammenlignet med medbragte madpakker. Da skolemaden ikke længere var gratis, benyttede få elever muligheden for at købe skolemad og der blev ved denne måling ikke målt nogen effekt af skolemadsordningerne. Der var ikke nogen forskel i den ernæringsmæssige effekt af skolemadsordningerne afhængig af alder.

Den standardiserede digitale fotometode viste sig at have en god validitet og reliabilitet i forhold til vurdering af den ernæringsmæssige kvalitet af medbragte madpakker. Desuden viste det udviklede Meal IQ sig at være validt og et brugbart evalueringsredskab til vurdering af den ernæringsmæssige kvalitet af skolemad og medbragte madpakker.

Der bør i fremtiden arbejdes med at forfine kostregistreringsmetoder. Udnyttelse af teknologien ved kostregistrering kan være med til at mindske byrden for forskeren og derved gøre den digitale fotometode mere cost-effektiv og muligvis mere akkurat. Et relevant perspektiv vil ligeledes være at udvikle den digitale fotometode så den kan bruges til at estimere kostindtaget hos 'fritlevende' børn.

Fremtidig forskning bør fokusere på at udvikle multikomponent skolebaserede interventioner, som tager hensyn til, at mange faktorer og arenaer kan have indflydelse på børns kostvaner. Fokus for en sådan intervention kan være implementering af vedvarende skolemadsordninger. Et andet fokus kunne være at forbedre de madpakker, børn har med hjemmefra med det formål at bidrage til at skabe en sund kostadfærd hos danske skoleelever.

1. Background

School food programmes were part of the political agenda when the Danish Government in 2007 announced a project where school food programmes should be tested and evaluated in the Danish school setting. One of the overall goals of this health promotion initiative was to improve the dietary habits of Danish school children. The Danish Food Industry Agency gave funds to 38 schools so that they could implement a school food programme, with a period of two months where the school meals were for free followed by a period where the students could buy the school meals.

In Denmark it has been common practice that most children bring their school meal from home. However, several initiatives with school food programmes have been introduced with one of the main objectives to improve the dietary habits of school-aged children. Very few studies have evaluated school food programmes in Denmark. The school food programmes which exist in Denmark are often paid by the parents or at least partly by the parents (1) and the proportion of users is usually not very high (2,3). The limited use of the existing school food programmes complicates the conditions for designing powerful studies which can contribute to the evidence of the effectiveness of school food programmes. This political initiative has given the opportunity to do a qualified evaluation study of the area.

In total 85 % of children in Denmark in the age of 7-14 years eat a packed lunch (4). Especially the youngest school children (7-10 years) bring their lunch from home. They are comfortable with their packed lunches which they connect with their parents (5). The prevalence of children who bring their lunch from home decreases with age (4). This could be due to the starting youth culture, which influences the status of the packed lunch brought from home (5). Thus the effect of implementation of a school food programme may depend on the age of the children. Studies have shown different results for different age groups. Bruselius-Jensen (6) found in a cross-sectional study among Danish school children that the children had different attitudes toward school food programmes, according to age. The youngest children in the 3rd grade seemed to like the packed lunches but children in the 6th grade were happier with the school food meals. Brown and Summerbell (7) made a systematic review to determine the effect of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity. They found that some interventions appeared to vary in effectiveness according to age of the children.

1.1 Dietary issues among school aged children

Healthy dietary habits during childhood promote optimal health, growth and cognitive development of the child, and may contribute to the prevention of chronic disease in later life (8,9). Childhood represents an important life stage for the development of healthy nutritional behaviour because some evidence exists, that nutritional behaviour track from childhood into adulthood (10,11). Thus, it is important to establish healthy dietary habits early in life.

Data from the Danish National Survey of Dietary Habits and Physical Activity 2003-2008 (12) revealed that to meet the official nutrition recommendations (13) and the dietary guidelines (14), Danish children should eat less fat and especially saturated fat and less added sugar. Furthermore the children should increase their intake of fruits, vegetables, whole grain and fish (Table 1.1).

Table 1.1: Dietary intake of average macro nutrients and selected food groups in children aged 7-13 years compared to the official nutrition recommendations and dietary guidelines

Nutrient and foods	Actual intake 7-13 years[1]	Danish[2]/Nordic[3] recommendations
Total fat (E%)	33	25-35
Saturated fat (E%)	14	Max 10
Protein (E%)	14	10-20
Carbohydrate (E%)	52	50-60
Added sugar (E%)	13	Max. 10
Dietary fiber (g/MJ)	2.0	3.0
Whole grain (g/10 MJ)	33	75[4]
Fruit and vegetables (g/day)	231/208[5]	400/600[5]
Fish (g/week)	70	200

E%: percentage of energy
[1] (12), [2] (14), [3] (13), [4] (15), [5] up to 11 years of age the recommendation is 400g/day and from 11 years the recommendation follow the one for adults

Data on children's lunch on week days almost look similar to the general average described in Table 1.1, except from the intake of whole grain, dietary fiber and added sugar (12). The lunch contributes around 50 % of the average daily intake of whole grain (15) and the content of dietary fiber in the lunch meals is higher (3.1 g/MJ) than the average daily intake. Added sugar contributes with 7 percentage of energy (E%) in the lunch meals (12,13). Thus whole grain, dietary fiber and added sugar are not issues in the lunch meals among children aged 7-13 years.

Thus, there is a high potential for improving the dietary habits of the Danish school children as well as the average daily diet as the intake at lunch, and therefore for promoting optimal health, growth and cognitive development.

1.2 Factors affecting dietary habits among children – conceptual framework

Many interventions have focused on individual-level behavioral determinants, such as increasing knowledge, awareness, attitudes and motivation (16,17).

However, dietary habits are influenced by a complex interaction between lots of factors across different contexts. Hence, calls have been made for interventions that take into account the wider environment (18). Figure 1.1 illustrates an ecological framework which is useful to consider when studying eating behavior among children. The model is modified after Story et al. (19). The conceptual framework shows that the food choice and eating behavior of children are affected by multiple levels of interacting influences: individual factors, e.g. cognitions, gender, age, taste preferences, which can influence food choices through characteristics such as motivations, self-efficacy, outcome expectation, and behavioral capability. The social environmental factors, e.g. interactions with family, friends, and peers may impact the eating behavior through role modeling, social support and social norms. The physical environmental factors are the many different settings where we eat, e.g. at home, in school, at work, at restaurants or buy food as in supermarkets. All these settings affect the eating behavior, while influencing the availability and accessibility of food and impact the barriers and opportunities that facilitate or hinder healthy eating. The last environmental context related to eating behavior in this conceptual framework is the macro-level environmental factors, e.g. food policies, marketing and economic price structures (19).

The focus of this thesis from the point of view from this ecological framework is to make changes in the physical environment and make a healthy school meal available/accessible in the school setting, see markings in Figure 1.1.

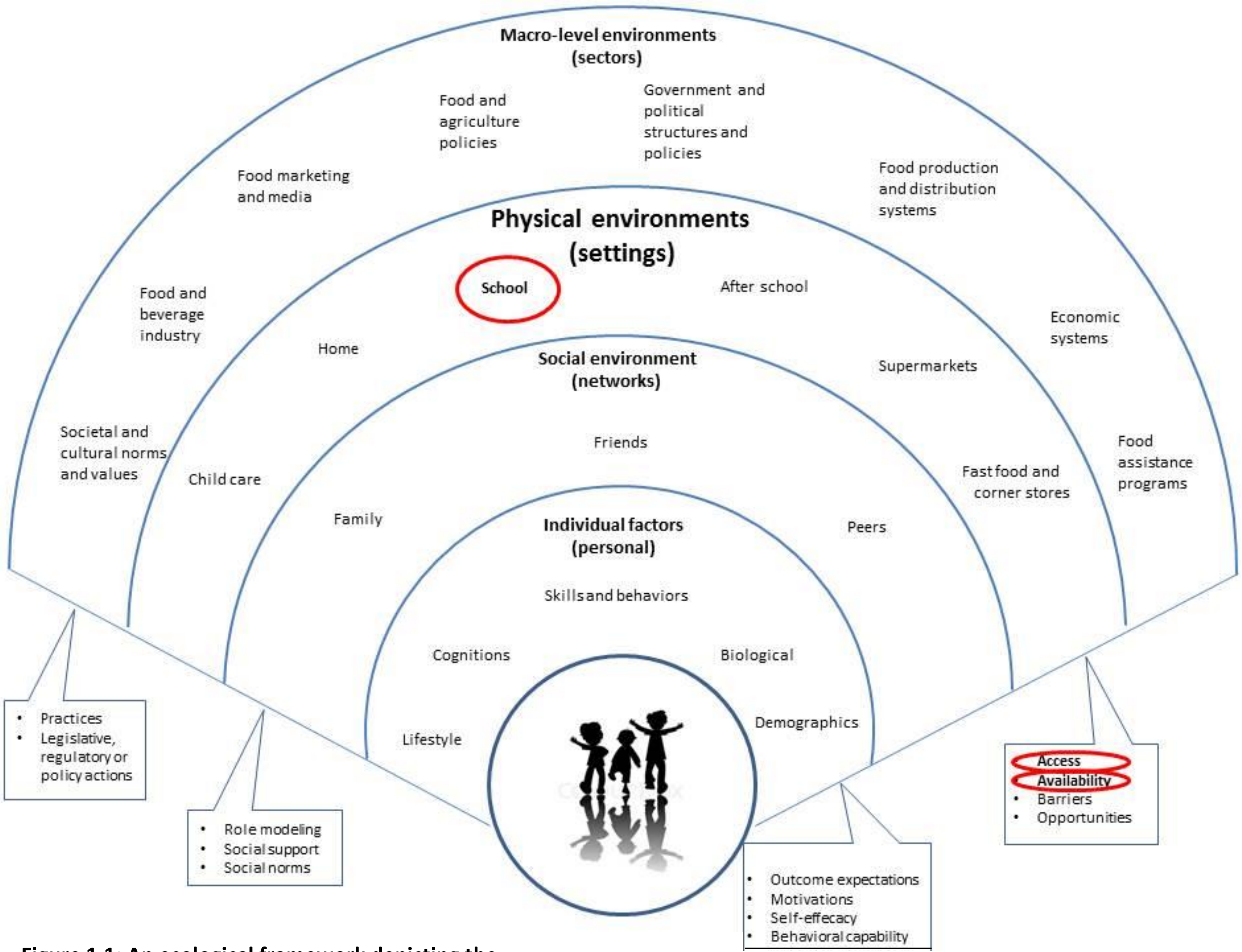


Figure 1.1: An ecological framework depicting the multiple influences on what children eat. Modified from Story et al. (24)

1.3 School environment

The school has been recognized as an important setting for health promotion, especially with the purpose to improve dietary habits among children (20-25), because the schools offer continuous, intensive contact with children. Schools reach all school-aged children of diverse ethnic and socio-economic groups and offer an environment that is accessible to all on equal terms. Furthermore healthy eating during the school day may enhance learning (25-27), though Müller et al. (28) did not find an effect on short-term cognitive functioning.

Despite the fact that school life varies enormously from country to country, there is one aspect in common, namely the fact that a proper lunch is essential when spending a long day at school. However, the ways of meeting this need are extremely varied. This applies just as much to the various dietary habits as to the practical framework governing the consumption of food. The different practical arrangements range from schemes where the food is simply based on packed lunches brought from home as in Denmark to those where snacks, finger foods and wraps are sold from tuck shops to well-established schemes where the food is centrally prepared and served in dedicated canteens. There is also a difference in whether the food constitutes a main meal or a morning snack or a between-meal snack just as there are numerous different traditions applying to the financial subsidies given to the various schemes (23).

1.3.2 Dietary quality of packed lunches compared to school meals

<u>School-based interventions</u>

A literature search using DTU Digital Library[1] was conducted and revealed that many school-based intervention studies on changes in dietary behavior and/or weight management in relation to obesity have been tested and evaluated. However, the studies were very heterogeneous in terms of design, number and age of participants, intervention (nutrition education, environmental interventions or multicomponent interventions), methodologies, outcomes, results and duration, making it difficult to generalize about the effect.

Several reviews have been published to clarify the effect of school-based interventions. Brown and Summerbell (7) made a systematic review to determine the effectiveness of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity. They included 38 studies. They conclude that there is insufficient evidence to assess the effectiveness of dietary

[1] DTU Digital Library is a comprised data base where a cross-search in all resources can be done - the data base includes the references from PubMed and Web of Science

interventions on measures of obesity. The findings are inconsistent, but overall they suggest that combined diet and physical activity interventions may help to prevent children becoming overweight in the long term. With few exceptions, many of the interventions have been conducted in the USA and Australia, which raises questions about the applicability of their results in European countries. Furthermore the primary outcome is measures of obesity, thus there could be some effects on dietary behavior which are not reported.

Cauwenberghe et al. (29) did a review on 42 studies with the purpose to summarize the effectiveness of school-based interventions to promote a healthy diet in children (6-12 years) and adolescents (13-18 years) in European Union countries. They concluded that in children (6-12 years) there were strong evidence of effect for multicomponent interventions on fruit and vegetable intake. The effect found for educational interventions on behavior and for environmental interventions on fruit and vegetable intakes was limited. The overall conclusion was that evidence was found for the effectiveness of especially multicomponent interventions promoting a healthy diet in school-aged children on self-reported dietary behavior.

De Bourdeaudhuij et al. (30) included 11 studies in their review. They reviewed the evidence of school-based interventions promoting a healthy diet together with healthy physical activity habits on behavioral determinants, healthy diets and physical activity habits, and measures of obesity in primary and secondary school children in Europe. In younger children (6-12 years) there was inconclusive evidence that multicomponent interventions have positive impact on child obesity in the European context. But they also conclude that there is moderate evidence that multicomponent interventions focusing on healthy diets and physical activity habits and combining an educational and an environmental component had a positive impact upon obesity measures in adolescent girls. Overall they suggest that combining educational and environmental components that focus on both healthy diet and physical activity give better and more relevant effects.

However, when implementing comprehensive multicomponent interventions, it is difficult to determine which components contributed to the effects. The most ideal situation would be to test the effects of intervention components separately before launching the comprehensive programme. As described in section 1.2 the focus of this thesis is to test the effect of changes in the physical environment while making a healthy school meal available/accessible in the school setting.

<u>Cross-sectional studies</u>

We found no school-based intervention studies investigating the dietary effect of substituting the packed lunch brought from home with a school meal provided by the school. Instead many cross-sectional studies exist, investigating student's dietary intake from packed lunches compared to school meals (31-53). Cross-sectional studies are ranked lower than the intervention studies in the hierarchical structure of studies according to their ability to provide evidence for causal relationships.

Evans et al.(36) conducted a meta-analysis, including 7 studies, where they compared British school meals and packed lunches from 1990 to 2007 measuring lunchtime nutrient intake in children aged 5-11 years. They found a higher intake of energy, sugar, non-milk extrinsic sugar, saturated fat and sodium intake from packed lunches compared with school meals. Packed lunches were nutritionally superior to school meals in one respect, namely Fe. Levels of protein, folate, vitamin C and Zn were broadly similar in both lunch types. Results for total fat, dietary fiber, Ca and vitamin A were less consistent, with less evidence of differences by lunch type. Evans et al. concluded that the nutritional quality of packed lunches is poor compared with school meals (39).

In general, the results of the studies and the meta-analysis indicate that eating a lunch brought from home is associated with a lower dietary quality of the lunch meal compared with the school meals. The most consistent results of the studies are that pupils eating lunches brought from home consumed more saturated fat and added sugar (40,43,45,47,49,50,54). Many report that most lunches brought from home contained energy-dense foods such as crisps, cakes or snacks (36,50,55) . Sodium is also reported as higher in the lunches brought from home compared to school meals (40,47,50). The results of energy, total fat, fruit, vegetables, vitamins and minerals were more inconsistent.

Dietary patterns vary over countries. Thus, there is need for studies in Denmark, investigating the difference between dietary quality of lunch consumed when children eat whether packed lunches or school meals. An intervention study would provide to the most credible evidence.

1.4 Assessment of children's dietary intake

It is a challenge to assess children's dietary intake. The assessment may be complicated, and inaccurate reporting from both children and parents in dietary surveys has been recognised as a major challenge (56,57). Parents may provide detailed accounts of what their children eat at home, but many are not able to give accurate information of what they consume at school (58). Weighed food records, food diaries, food frequency questionnaires, diet histories, and 24-h dietary recalls are all common methods for estimating dietary intake; however, these methods rely on self-reporting with a relatively high respondent burden (59). The accuracy of self-reported methods has been questioned (60). The gold standard for measuring food intake in free-living people is the doubly labelled water (DLW). Studies using DLW have shown that mis-reporting of food intake is a common problem for these methods (61-63). Especially when collecting data on dietary intake in paediatric populations, self-reported methods become a challenge. When children are responsible for reporting their own intake, issues of literacy, writing skills, memory constraints and concentration span are of particular concern. Foster et al. (64) have observed a great deal of variation in the ability to recall foods consumed within any one age group. This may be dependent on an individual's cognitive development, interest in food, and the attention paid to mealtimes. Baxter (57) reported from a summary of 12 dietary-reporting methodological studies with children aged 9-10 years the retention interval to be crucial for the accuracy of the recalls. Furthermore, recalls obtained with an open format were better than a meal format. Before the age of 12 years, children's recall skills, ability to estimate and indicate portion size, and knowledge of foods are limited, and they may not yet have developed the cognitive skills required by the self-reported methods constraining their ability to self-report their food intake without parental assistance (56).

The quantification of food intake may be complicated, and the estimation of portion size has been shown to be the largest source of error in estimating food intake from self-report in a study among 39 adults (65). Extensive training in estimating portion sizes was in a study found to improve the skills of a group of 44 overweight adults, though a large degree of variability in portion size estimates remained (66). Also among children the quantification of the dietary intake is a particular challenge (56,64,67).

Thus, there is a need for an alternative valid method which do not rely on the respondents to estimate portion sizes and a method which overcomes the recall problems that exist in collecting dietary data on children. Such methods are sparse. The direct visual estimation technique and the digital photographic method (DPM) are different from the more traditionally self-reported dietary assessment methods. Both methods could solve children's recall problems and difficulties in portion estimation. The interaction with the participants are minimal and thus the burden of the respondent. The advantages using the DPM instead of the visual estimation technique may be: more rapid collection of the dietary data in the eating environment, possibility of collecting data from a large sample, more convenience for participants and researchers, and the possibility of uninterrupted evaluations of the foods that are studied on the digital images, as opposed to evaluation in the setting for data collection (68).

1.5 The digital photographic method (DPM)

The DPM involves different steps from taking the images of food selection and food waste to subsequent portion size estimation and evaluation of the nutritional quality (Figure 1.2).

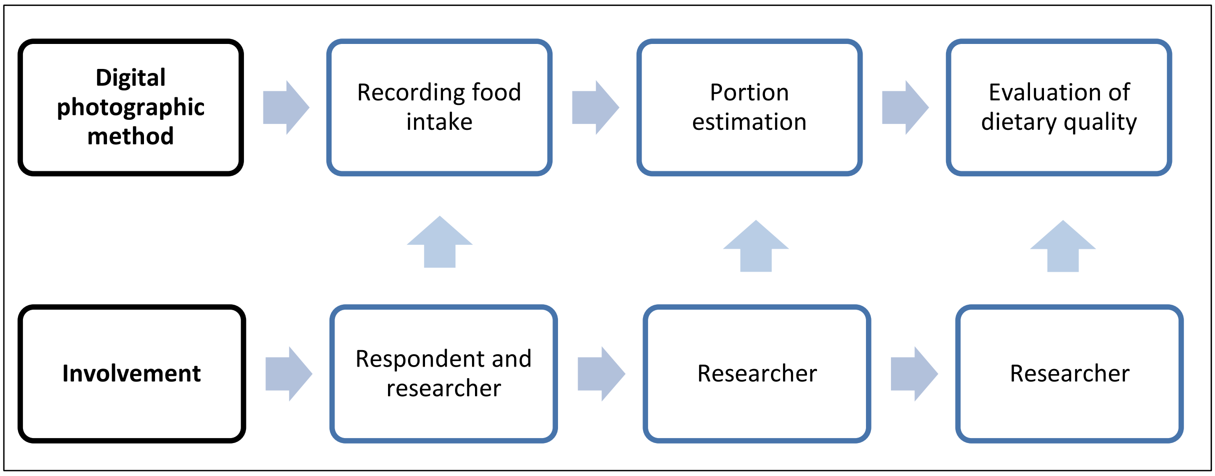


Figure 1.2: Illustration of the steps involved in the digital photographic method and involvement of the respondent and researcher

The DPM was developed to unobtrusively measure food intake in cafeteria settings and has been used at universities (69) schools (70,71) military barracks (72) nursing homes (73) and laboratory facilities (68,74).

Martin et al. (71) tested the reliability and validity of measuring children's food intake with the DPM. Food intake was measured in a school cafeteria for 5 days. The method was reported to be reliable. In this study Martin et al. found a significant association between food intake and adiposity (BMI percentile) supporting convergent validity. Swanson (70) also used the DPM in the school setting at 2 elementary schools, where the children's trays were photographed. Swanson concluded that the DPM is reliable and cost-effective to measure actual consumption of school cafeteria meals. Each tray took less than 5 seconds to situate and photograph. Williamson et al. (68) tested the validity of the DPM against weighed foods of 60 test meals. The study supported the validity of the DPM for measuring portion sizes. They also tested the method in a university cafeteria during a single day and found the method to be valid compared to the direct visual estimation technique (69).

Swanson et al. argued that the DPM is cost-effective (70). The DPM offers researchers an important tool to collect data on the dietary intake in a resource- and time-effective manner. Thus the method may be useful for collecting data from a large population and thereby the method may be appropriate for evaluation of large-scale intervention studies where impact on dietary behavior is measured.

Thus the DPM overcomes children's recall problems and difficulties in estimating portion sized and it also minimizes the burden of the respondent. The method has shown to be reliable and valid when used to estimate the food intake of individual meals of adults and school children in cafeteria settings. Furthermore, the DPM is usable for collecting data from a large sample. In Denmark most children eat a packed lunch brought from home. Thus, if the dietary effect of a school food programme has to be evaluated the school meals provided have to be compared with packed lunches. To our knowledge, the DPM has not been tested on packed lunches brought from home among school children.

1.6 Evaluation of dietary quality

The recording of food intake is easily obtained using the DPM. The estimation of portion sizes and evaluation of dietary quality relies on the researcher (Figure 1.2). Often the dietary intake is calculated from weights of the food items. For the evaluation of a school food programme including many participants a simpler tool is needed. In this study the tool had to be flexible with regard to the different types of meals (packed lunches and school meals), and it also had to be sensitive enough to measure relevant differences when children eat school meals instead of packed lunches.

Many epidemiological studies that focus on the relationship between diet and risk of chronic disease, investigate the intake of a single nutrient, food or food group. However, this approach does not consider the complexity of dietary behavior, as food and nutrients are not eaten in isolation.

1.6.1 Diet quality indices

A numerous of varying indices has been developed. Indices of dietary quality, patterns and variety have been used to address the complexity of dietary behavior and to provide a measure of the overall quality of dietary habits. These indices are often based on dietary recommendations designed to reduce the risk of chronic diseases (75-77).

The development of the indices may use the same approach as the nutrient profiling approach. The nutrient profiling has been defined as "categorization of foods for specific purposes on basis of their nutrient composition according to scientific principles" (78). The purposes can be divided into the following points: 1. the evaluation of the nutritional quality of single foods, 2. to help consumers make a 'healthy' food choice, 3. to regulate the promotion of foods to children, and 4. to identify food products eligible to bear a nutrition or health claim (79).

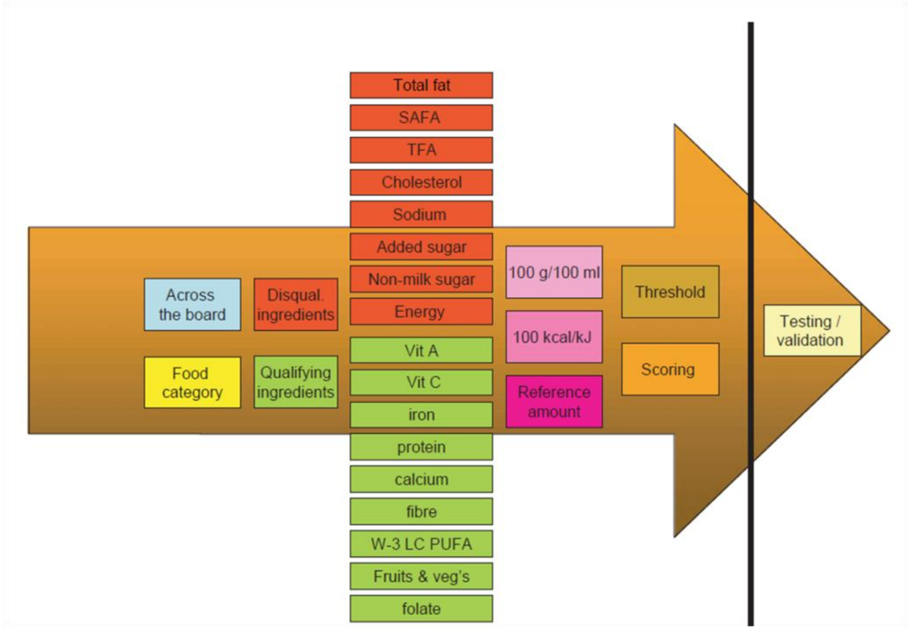


Figure 1.3: A simple visual model to compare existing nutrient profiling schemes; basic figure (79)

Verhagen and van den Berg (79) have visualized the different choices which can be made in the nutrient profiling approach (Figure 1.3). A choice between a system based on food categories and/or ‘across the board’, a choice between qualifying (nutrients or foods in the green boxes (Figure 1.3)) and/or disqualifying ingredients (nutrients or foods in the red boxes), a choice for the reference base, which can be per 100g/100 ml, 100 kcal/100 kJ, and/or per reference quantity/serving, and a choice between a scoring system or a threshold system. When all the individual choices have been made and agreed upon, the system of choices needs to be validated and tested.

The Indices of diet quality are predefined summary measures of overall diet quality. Dietary indices have mainly been developed for adults (80-86) but determination of indices specific for children have also been done and published (87-89). The Revised Children’s Diet Quality Index (RC-DQI) (87) and the Preschoolers Diet-Lifestyle Index (PDL-index) (88) are tools for ascertainment of dietary quality on preschoolers. The Youth Healthy Eating Index (YHEI) has been developed and used for children and adolescents (89).

Although all the indices aim to show the overall quality of diet the different indices often focus on specific food features, depending on the contexts and objectives of their usage. The numbers of components vary a lot. Some indices are based on intakes of nutrients (90), some on consumption of specific foods or food groups (85,88,89), and then there are indices that combine both nutrients and foods (80-82,87,91,92).

Furthermore, the indices reflect the dietary quality for different periods of time and based on different assessment methods. Most indices assess the dietary quality of the total diet, but indices which focus on the dietary quality of single meals, including school meals, remain limited. Lassen et al. (91) developed a Simple Healthy Meal Index (SHMI) for use on single meals, the target group was adults and the setting was canteens at workplaces. Kremer et al. (93) developed a school food checklist with food and beverage categories, which was designed to estimate children's average energy intake from foods and beverages available in a school setting. The focus was on the quantity of the meal, measured by the energy content, and not on the quality.

1.7 Summary

Healthy dietary habits are important for promoting optimal health, growth and cognitive development in children. There is a high potential for improving the dietary habits of Danish school children. Eating behaviour is highly complex and results from the interplay of multiple influences across different contexts. The school setting is popular for health promotion initiatives which are a plausible solution for the purpose to improve dietary habits among children. It is important to design studies with enough power to give credible evidence to the aims which are explored. To investigate if school food programmes have an effect on the dietary intake of children at school it is important to use valid and reliable methods/tools for evaluating such health promotion initiatives. Methods for measuring and assessing the dietary quality of the lunch children eat at school are needed. It is a challenge to assess children's dietary intake because of recall problems and difficulties in estimation of portion sizes by this population. Compared to the more traditional dietary assessment methods the DPM may overcome these challenges while having minimal interaction with the respondents. Indices are a possible tool to use for assessment of overall dietary quality and this method is also possible to combine with the DPM. The index has to be simple and flexible with regard to the different types of meals, and it also has to be sensitive enough to measure relevant differences when children eat school meals instead of packed lunches. Age may influence the effect of a school food programme.

2. Aim of the PhD study

The aim of this PhD thesis was to evaluate the dietary effect of a school food programme in Danish schools on the quality of lunch consumed by children aged 7-13 years. Furthermore, the aim was to develop appropriate methods for assessing dietary intake for evaluation of interventions in the school setting.

Specific objectives were as follows:

- To evaluate the validity and reliability of a digital photographic method to assess the quality of dietary intake from packed lunches brought from home (paper I).
- To develop and validate an index for assessment of dietary quality of packed lunches brought from home or school meals provided by the school (paper II).
- To evaluate the effect of implementing a school food programme on the dietary quality of lunches consumed by school children compared with packed lunches brought from home, and to investigate if a possible effect would differ between the youngest school children and the older (paper III).

3. Methods

The Danish Food Industry Agency started in 2008 a school food programme with the purpose to improve the dietary quality of school children's lunch intake. To evaluate this initiative a controlled intervention study was designed and conducted. To be able to measure the dietary effect of the school food programme on the quality of children's dietary intake at lunch new methods for measuring and assessment of the dietary intake among school children was developed and validated. This section is separated into two parts – first the study design and the methods used in the intervention study are described and second the validation of the methods developed and applied in the study are explained.

3.1 Intervention study/main study

3.1.1 Study design and sample

The present study was designed as a quasi-experimental pre- and post-intervention study.

Sample size calculations was based on 80% power and 95% confidence and aimed at a difference in saturated fat in the lunch meal from 7.8 g before the intervention to a content which meet the nutritional recommendations (13) on 5.5 g in the intervention period. To detect at least this difference we needed 4 clusters with minimum 50 children in each group. The recruitment was done in school classes and though we expected a high compliance the recruitment procedure resulted in more than 50 students in most of the clusters going from 53-71.

Thus 4 intervention schools of the 38 schools, which received funds, were selected, taking into account representation of different geographic locations. Four control schools were selected among schools without any school food programme and matched with the 4 intervention schools regarding municipality, school size and families' social background.

At baseline 984 school children were included in the classes recruited to the study - 493 children from 2nd and 3rd grades and 491 children from the 5th and 6th grades. Figure 3.1 illustrates the flow of schools, participants and number of meals included in the analyses.

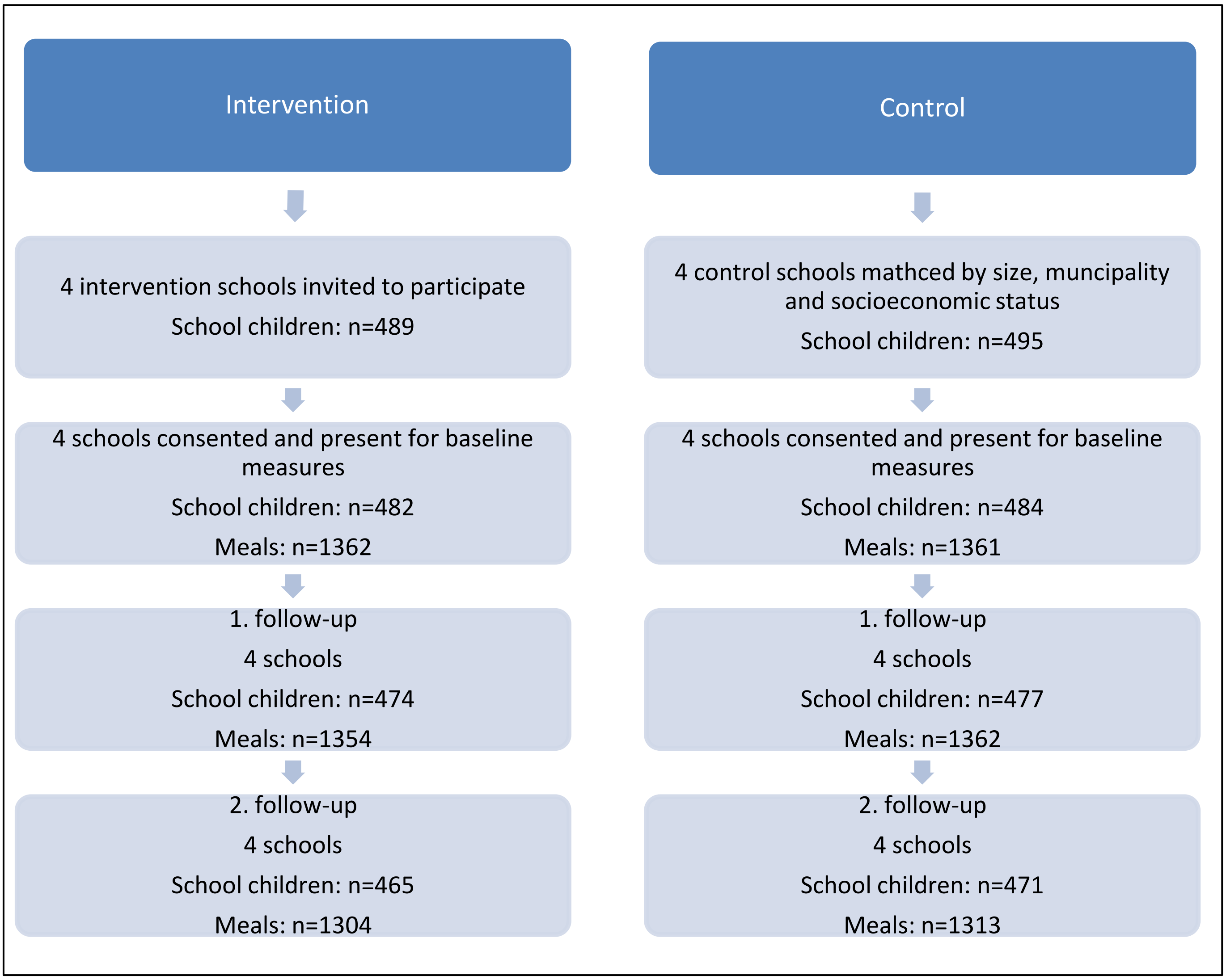


Figure 3.1: Flow of schools, participants and meals through study

3.1.2 Dietary intervention

The data collection was conducted in the school year 2008/2009 during August-December 2008 and February-April 2009. Data was collected successively on the 8 schools. One or two weeks after data were collected on an intervention school collection of data took place on the matched control school. Baseline data were collected just before the intervention period began. The 1st follow-up was 8 weeks after baseline and 2nd follow-up was 6 month after baseline (Table 3.1).

Table 3.1: Participating schools, geographic location, number of students, indication of the free period and time for the 3 data collections

School	Geographic region	Number of students	Period with free school meal (week 2008)	Baseline (week 2008)	1st follow-up (week 2008)	2nd follow-up (week 2009)
School 1	Southern Denmark	360	(36-44)	34	43	9
School 2	Southern Denmark	630	(38-46)	35	44	10
School 3*	Southern Denmark	422	-	36	45	11
School4*	Southern Denmark	524	-	37	46	12
School 5	Region Middle Jutland	385	(39-47)	38	47	13
School 6	Zealand	780	(40-50)	39	49	14
School 7*	Region Middle Jutland	500	-	40	48	16
School 8*	Zealand	412	-	41	50	17

*Control schools

At baseline data on packed lunches were collected in both intervention and control schools. At 1st follow-up the children at the control schools had lunches brought from home, and the intervention schools received free school meal. At 2nd follow-up the control group were having lunch brought from home and at the intervention schools the school meals were no longer for free, so the school children were either having paid school meals or lunches brought from home (Figure 3.2).

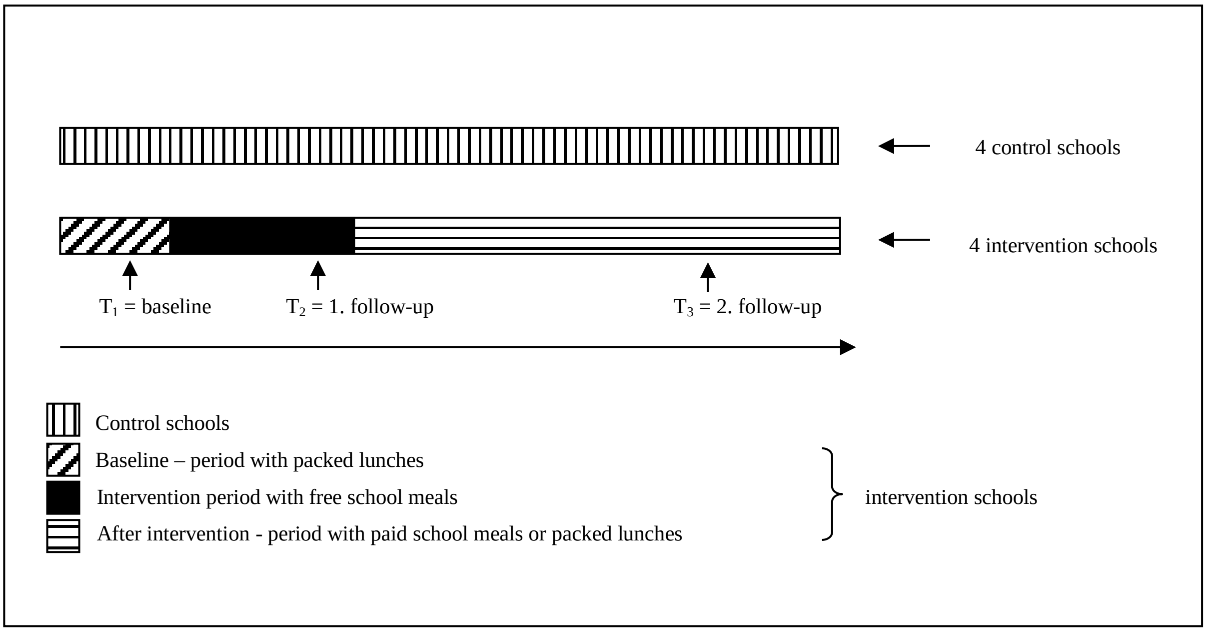


Figure 3.2: Study design

Each of the three measurement periods (baseline, 1st and 2nd follow-up) data on dietary intake were collected for 3 days during a week to cover the variability of the lunches.

Written information on the study was given to the teachers and the parents. If the parents had further questions they were able to call a project manager. The study was approved by the Danish Data Protection Agency.

3.1.3 Digital photographic method (DPM)

To estimate the dietary intake of the packed lunches or the school meals a standardized DPM was developed and used. The meals were photographed using a digital camera (Nikon S700) mounted on a tripod with the lens 0.37 metres above the meal with a camera angle of approximately 45° – a procedure that allows visibility of the foods in three dimensions in a digital image. To standardize the digital images, a placemat (0.6x0.6 m) with markings for placement of the plate and some standardized cutlery were fixed to a table. The placemat was divided into squares of 2x2 cm to support the estimation of the size and weight of the different food items. Figure 3.3 shows a sketch of the placemat, the f's at the sketch indicate where the fork was placed and between the k's where the knife was placed. Markings were also made for where to place the feet of the camera tripod (a). The c's indicate the centrum for the placement of the plate. The b's on the sketch indicate a line, which were used for the setup of the camera in the right angle. The line between the b's was used as a focus point and was in the bottom of the picture taken. The placemat was laminated with a matte lamination (125 mic.).

To optimize and standardize the quality of the digital images, a cube light was used (Figure 3.4). The research staff attended a training session on the use of the DPM before the data were collected.

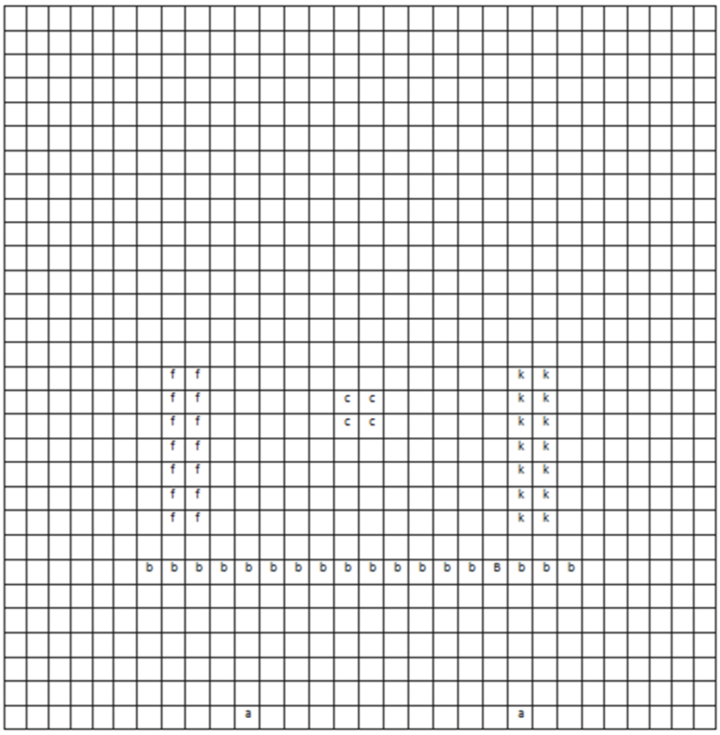


Figure 3.3: Sketch of placemat used for the standardized digital photographic method (**a: placement of the feet of the camera tripod, b: focus line, c: centrum of the plate, f: placement of the fork, k: placement of the knife)**

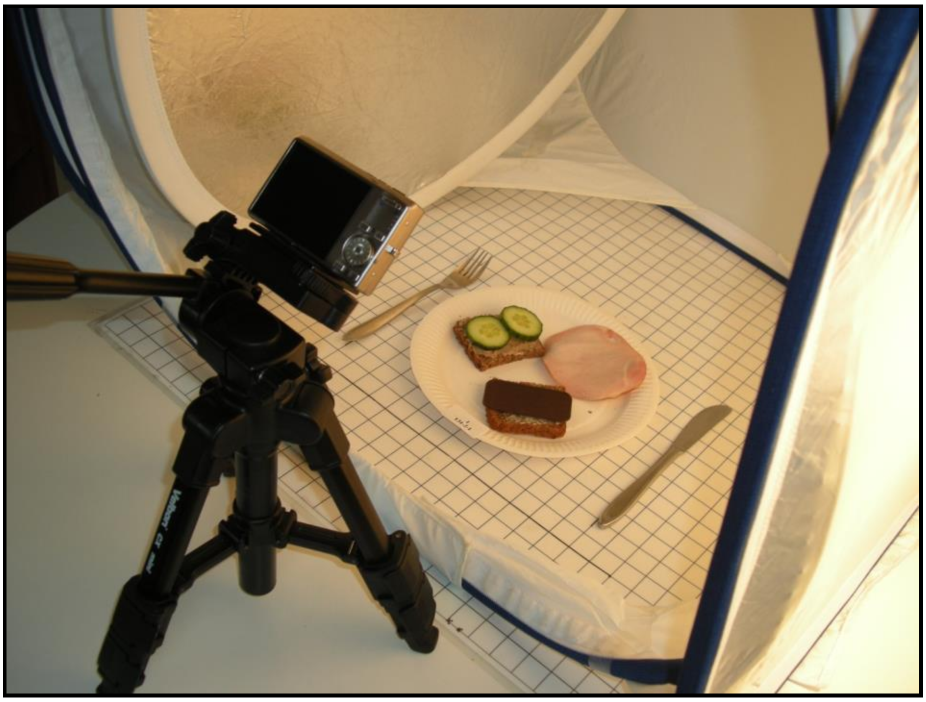


Figure 3.4: The standardized digital photographic method

The children placed their lunches on a plate, which was distributed to them. At the beginning of the lunch break all the meals were photographed individually. At the end of the lunch break, the plates were again photographed this time with or without leftovers (Figure 3.5).

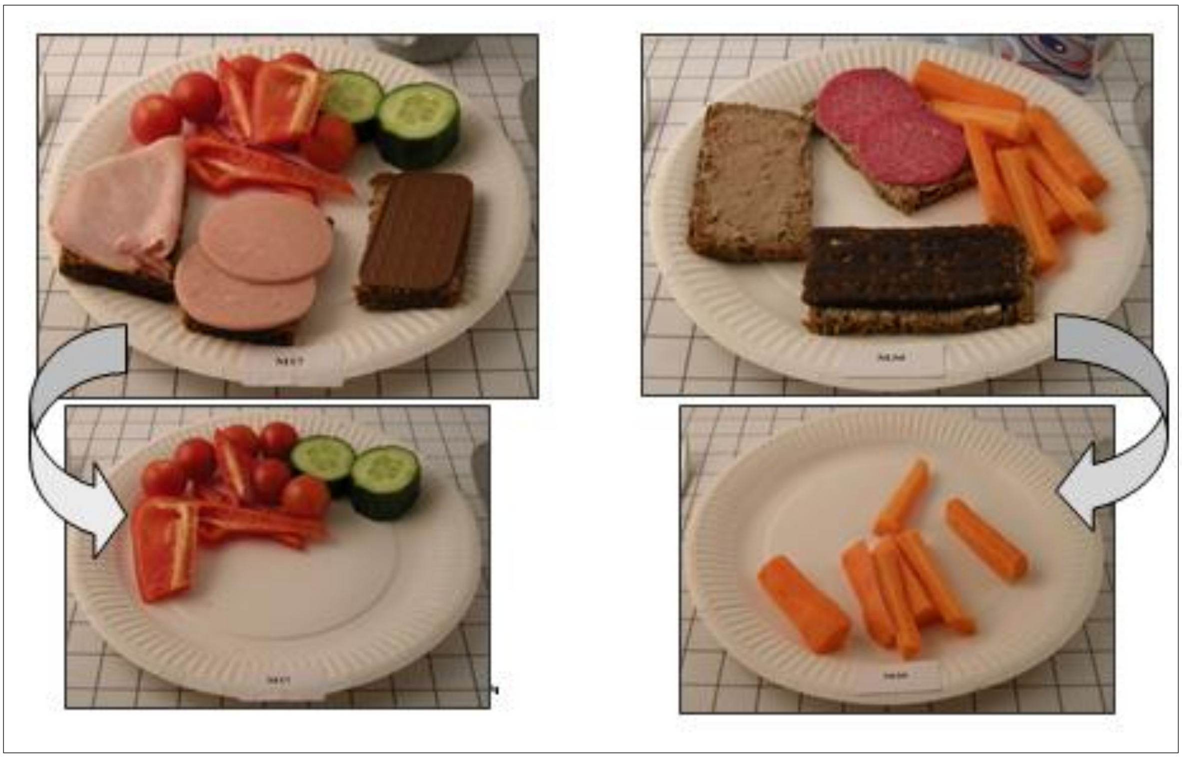


Figure 3.5: Two examples of starting meals and leftovers

The children were instructed to place the food on the plate so it was possible to see the different components of the meal, e.g. if the child had a sandwich they were asked to open the sandwich for viewing. In addition, for non-visible food items, the participants were asked questions about specific food items if the research staff assessed that it would be difficult to see on the digital image.

School meals provided by the schools

Data on 31 school meals provided by the 4 interventions schools were collected during the intervention (T2) and at follow-up (T3) (Figure 3.2). Recipes and product specifications for these lunches were collected. The school meals were served as standard portions. Two of each school meals were bought and the weights of the food items registered. Digital images were also captured of the carefully measured standard portions of the meals served on the days of data collection.

3.1.4 Assessment of quality of dietary intake

A Meal Index of dietary quality (Meal IQ) was developed for assessment of the dietary intake.

<u>Development of the Meal Index of dietary Quality (Meal IQ)</u>

The development of the Meal IQ was inspired by the steps used in a nutrient profiling approach (79) and included: selection of variables; selection of measures for assessing the variables; definition of scoring systems and thresholds; and validation of the Meal IQ (Figure 3.6).

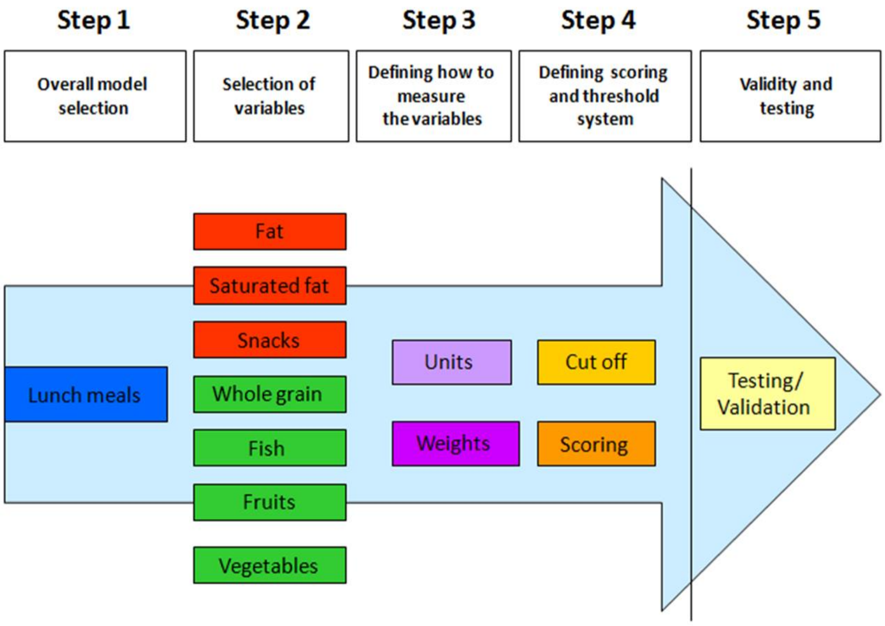


Figure 3.6: Steps in development of the Meal Index of dietary Quality. Modified from Varhagen & van den Berg (79)

The purpose of the index was to evaluate the overall dietary quality of lunch meals (packed lunches and school meals) and as part of creating a simple method for the evaluation of an intervention study the Meal IQ should build upon visibility so the dietary assessment could be done from a digital image.

The tool was developed for the purpose that encompasses dietary adequacy, variety, moderation, and balance and furthermore the selection of variables was based on the dietary issues that are particularly relevant to the lunches and general food intake of children aged 7-13 assessed by discrepancies between data from the Danish National Survey of Dietary Habits and Physical Activity on the actual dietary intake and the official nutrition recommendations and dietary guidelines. These considerations led to a Meal IQ consisting of seven components, which reflect the following nutrients and food groups: fat, saturated fat, snacks as a proxy for added sugar, whole grain, fish, fruits and vegetables.

The next step in the development was to define how the variables were measured. Fruit, vegetables and fish were estimated in grams and total fat, saturated fat, whole grain/potatoes and snack products were assessed using unit sizes (Table 3.2). These units were defined in terms of household measures such as slices, cups and pieces (91). A fat unit consisted of 5g fat. A starchy unit corresponded to 50g bread, 75g pasta or rice or 150g potatoes, 300g vegetables, 200g fruits and 35g dried fruits which corresponded to an energy content of about 400-500kJ (about 25g starch pr. unit) (91).

Table 3.2: Measurement of variables in the Meal Index of dietary Quality (Meal IQ)

Meal IQ components						
Units				Weights/grams		
Total fat	**Saturated fat**	**Whole grain* and potatoes**	**Snack products[§]**	**Fish**	**Fruit**	**Vegetables**
Estimate number of fat* and starchy† units Fat units subtracted from starchy food units.	Asses if fat units are animal-based	Assess if starchy units consist of whole grain or potatoes.	Assess if snack product is present and estimate the content of starch units of the snack product	Estimate amount in grams	Estimate amount in grams	Estimate amount in grams

*Fat unit: 5 g fat
† Starchy unit: 50 grams of bread (1 slice), 75 grams of pasta or rice (1 cup), 150 grams of potatoes(2-3 pieces), 300 grams of vegetables, 200 grams of fruits, 35 grams of dried fruits (energy content of about 400-500 kJ (about 25 grams of starch per unit)).
‡Whole grain products: ≥51 percent of the dry matter (15)
[§]Snack products: fat >10g/100g and/or saturated fat >4g/100g and/or added sugar >10g/100g (94)

Each of the seven components of the Meal IQ was scored from 0 (lack of compliance) to 4 (full compliance) with intermediate scores reflecting level of attainment toward dietary recommendations (13,14), but intake level in the population was also taken into consideration in defining the cut offs of the different component scores. The total score for the Meal IQ ranged from 0 to 28. The construction and criterion for scoring each component are listed in Table 3.3. (For description of validation see section 3.2.2).

Table 3.3: The Meal Index of dietary Quality (Meal IQ) scoring criterion for each of the seven components

	0 point	1 point	2 points	3 points	4 points
1. Total fat (units)	Starch-fat≤-1	-1< Starch-fat <-0.25	-0·25≤ Starch-fat ≤0.25	0.25< Starch-fat ≤1	Starch-fat >1
2. Saturated fat (units)	Sfa>3	3≤sfa<2	2≤sfa<1	1≤sfa<0	Sfa=0
3. Whole grain and potatoes (units)*	Whole grain=0	0<Whole grain ≤0.5	0.5< Whole grain ≤1	1< Whole grain ≤1.5	Whole grain >1.5
4. Snack products (Y/N) (units)†	Yes and starch units>0		Yes and starch units=0		No
5. Fish (g)	0	0-10	10-20	20-30	>30
6. Fruit (g)	0	0-17‡/0-25§	17-33‡/25-50§	33-50‡/50-75§	≥50‡/≥75§
7. Vegetables (g)	0	0-17‡/0-25§	17-33‡/25-50§	33-50‡/50-75§	≥50‡/≥75§

*Whole grain products have a content of whole grain ≥ 51 % of the dry matter (15).

†If no snack product is present in the meal 4 points is achieved. If the meal contains a snack product, then the score 0 or 2 could be given, if the contribution of starchy units is ≥ 0.5 units the score would be 0, but if the amount of the snack product is so limited that the contribution of starchy units is < 0.5 then the score 2 is given. A snack product is defined as having a nutrient content beyond the following limits: fat >10g/100 g and/or saturated fat>4g/100g and/or added sugar>10g/100g (94) .

‡Limits for children up to 11 years of age

§Limits for children from 11 years

3.1.5 Database for dietary assessment of digital images

A database was developed in Microsoft Excel for the dietary assessment of the digital images in order to make the necessary notes on the dietary components in the Meal IQ while watching the digital image (Figure 3.7). Reference material was developed for this purpose (see section 3.2.1 for more details).

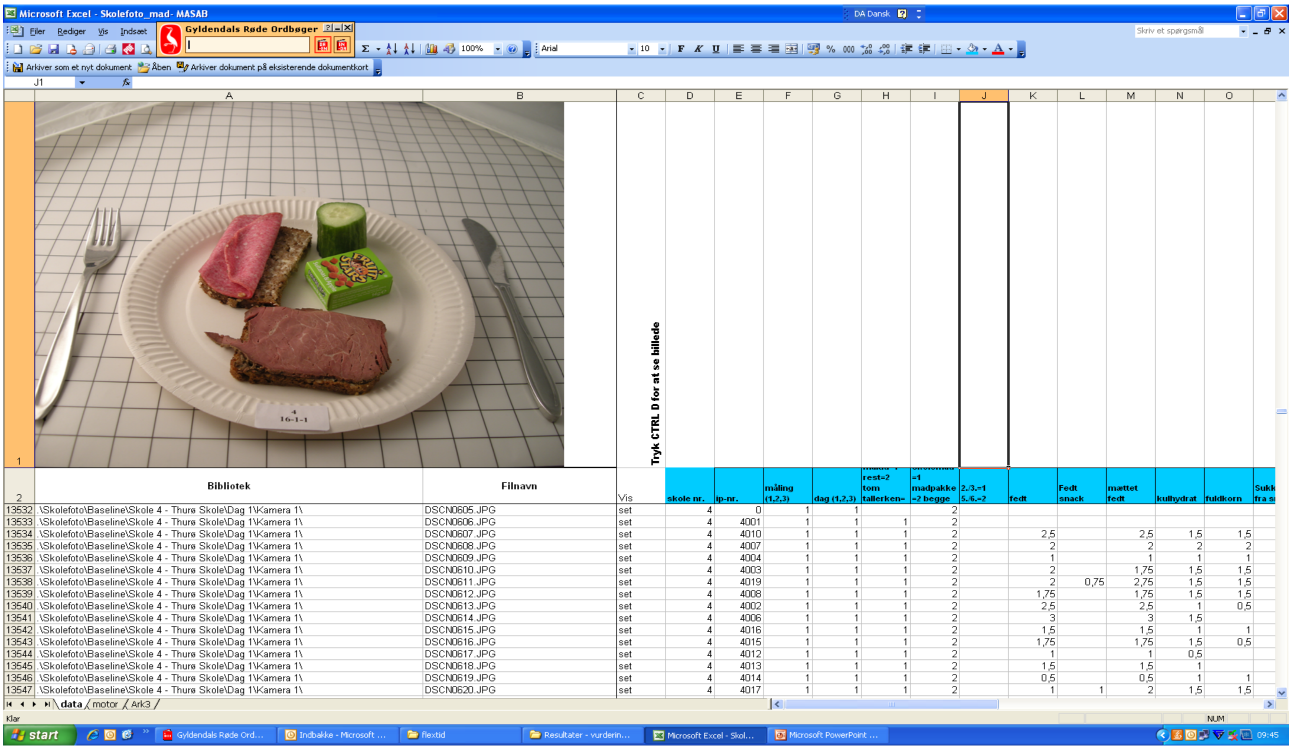


Figure 3.7: Database for dietary assessment of digital images

If there were any doubts about the food items on the digital image decisions were made based on consensus between the two recorders, if consensus was not possible the digital image was excluded from the study.

3.1.6 Self-report questionnaire/interview

Data on socio-demographic characteristic was assessed by questionnaire. The students from the 2nd and 3rd grades were interviewed and the students from the 5th and 6th grades filled out the questionnaires themselves. The majority of the questions used were developed, validated and used in the project Pro-children: Promotion and Sustaining Health through Increased Vegetables and Fruits consumption among European Schoolchildren (95). Answers from the questionnaire were used to assess the social background of the child's family using The Danish Occupational Social Class (DOSC) measure which includes 8 groups. Answers about mothers and fathers occupation were coded and a common measure for the family was constructed (96).

At the 2nd follow up the school children on the intervention schools were asked questions about their use and satisfaction with the school food programme, these questions were also assessed by questionnaire.

3.1.7 Anthropometrics

The height and weight of the students were measured to calculate body mass index (BMI; kg/m^2). The measures were taken in light clothing and without shoes. Weight was measured to the nearest 0.1 kg using a Soehnle Verona 63749 digital person scales, height was registered to the nearest 1.0 cm using a Soehnle 5003 digital height rod.

3.1.8 Training of field workers

The research staff attended a training session on the use of the DPM before the data collection started.

The field workers were also trained in using the questionnaire used for interviewing the youngest children. Furthermore the equipment for measuring the weight and the height of the children was tried by the fieldworkers and variation within and between fieldworkers was tested before but also during the study.

The two persons who analysed the digital images in the intervention study and in the validity study of the DPM conducted a training session, where ten packed lunches brought from home were used to train the image analysts in portion size estimation on the basis of the developed reference material - photographed reference foods and reference lists.

3.2 Validation of the methods used in the main study

The procedure of the validation of the DPM and the Meal IQ is illustrated in Figure 3.8.

3.2.1 Validation and reliability-testing of the digital photographic method (DPM)

To validate the DPM a sample of 192 digital images of packed lunches brought from home was selected. These lunches were selected randomly among 2735 packed lunches collected from the 8 participating schools at baseline. In total 24 packed lunches from each school, 12 packed lunches from each of the two age groups 2^{nd}-3^{rd} grades and 5^{th}-6^{th} grades. One meal was excluded from the validity study, because it only consisted of beverages. The sample size for validation of the DPM was chosen to ensure presence of all relevant food components examined in the dietary assessment procedure.

To create an objective reference method for the validation of the DPM the 191 packed lunches on the digital images were recreated. All occurring food items were bought. Afterwards the packed lunches were produced and in this process the weight of all food items in the lunches were registered. A digital image was taken of the 191 weighed and prepared lunches following the standardized procedure described above (Figure 3.4).

All weights were registered using a Soehnle 8026 digital balance (0-1,000 g = 1 g, 1,000-2,000 g = 2 g).

<u>Validation study – digital photographic method</u>

The Meal IQ was used to assess the dietary quality of the 191 packed lunches.

Reference method - weighed foods: As reference method the components of the Meal IQ and the total Meal IQ score were determined from the objectively weighed 191 packed lunches. Fruit, vegetables and fish were already registered in grams and while weights in grams were assigned to each of the units is was possible from the registered weights of the food items to calculate the number of fat, saturated fat, starchy and whole grain units. From the objectively calculated components from the weighed foods the Meal IQ score were obtained.

Test method – DPM: To test the validation of the DPM the components of the Meal IQ and the total Meal IQ score were also determined from the digital images, see Figure 3.8.

<u>Reference material</u>

To support the consistency of the conversion of food items in the digital images into weights and unit sizes, necessary for determination of the Meal IQ, reference material was developed.

The material consisted of photographed reference foods. Each food item was photographed in up to eight different portion sizes and prepared/cut in different ways. The food items were also photographed in different positions on the plate – at the back and the front and at one of the sides of the plate. The reference foods were selected to represent the foods most frequently consumed by children who brought a packed lunch from home, selected on the basis of the 191 meals representing the study sample. The total collection of the photographed reference foods consisted of 7 different fruits, 16 vegetables, 6 fish, 9 starchy foods such as bread, rice, pasta and potatoes, 22 fatty foods such as butter/spread, meat, and dressing.

In addition to the digital images of reference foods in different portion sizes the reference material consisted of lists with relevant information for the dietary assessment. Some food items are in standardized portions. These products were not photographed but instead presented in reference lists. There was a reference list for the fatty foods e.g. sliced meat containing information about typical portion sizes and information on content of fat pr. 100 g and pr. portion of the food item. Different fish products were also presented in a reference list with information on the content of fish in a mixed product, e.g. tuna salad. Information on starchy food products were also put in a reference list and in addition to the information of weight of standard portions information on if the product was categorised as a whole grain product was given. And finely a reference list of snack products and their content of fat and starch pr. standard portion was available. Data from GfK (Gesellschaft für Konsumforschung) Denmark (97) and from the Danish National Survey of Dietary Habits and Physical Activity (12) was used respectively to give information on the most used product of a category and to assess composite dishes or products for which no declaration was available.

The standardized DPM was validated testing the agreement of the dietary components included in the Meal IQ and the overall Meal IQ score obtained using the weighed foods and the digital images of the prepared packed lunches.

<u>Reliability testing of the digital photographic method</u>

Inter-rater reliability testing was conducted on the standardized DPM to assess the ability of the method to yield consistent results for the food components and the total Meal IQ score by two raters. The two digital images analysts' ratings were compared for each dietary component and the total Meal IQ score for the 191 digital images of the school meals.

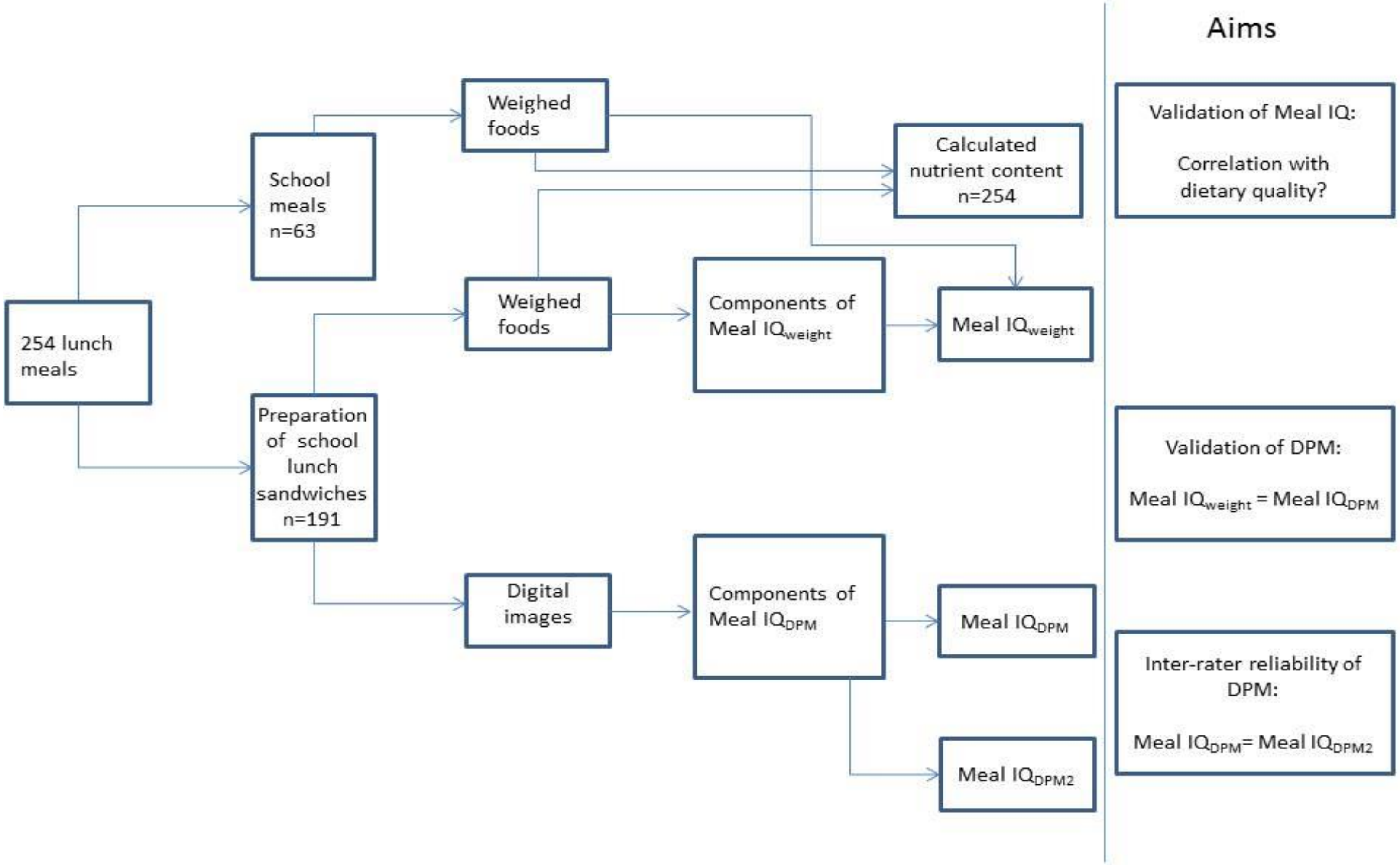


Figure 3.8: Procedure of validation of the digital photographic method and the Meal IQ

3.2.2 Validation of the Meal Index of dietary Quality (Meal IQ)

The same randomly selected sample of packed lunches as used in the validation of the DPM was used to evaluate the validity of the Meal IQ, see description above. To validate the Meal IQ the data on the weighed foods of the 191 packed lunches were used.

In addition to the packed lunches the total of 31 lunches provided by the schools and served to the students at 1st and 2nd follow-up were included in the sample. At the time data were collected a school meal was bought of each of the 31 school meals and the food items were weighed. Recipes and product specifications for the school meals were collected. To ensure a greater representativity of this type of lunches another 32 provided school meals were included in the study sample using the same procedure for data collection as for the other school meals. These meals were collected in another Danish study in 18 public schools, representative for Danish schools in terms of degree of urbanization and size (numbers of school children). These data were collected during November 2007-April 2008 (98).

In total, the study sample for validation of the Meal IQ consisted of data on weighed foods of 254 lunch meals – 191 packed lunches and 63 school meals provided by schools (Figure 3.8). All weights were registered using a Soehnle 8026 digital balance (0-1,000 g = 1 g, 1,000-2,000 g = 2 g).

<u>Validity study – Meal Index of dietary Quality</u>

From the weighed food records of the lunch meals the nutrient content was calculated. The nutrient calculations were conducted using the computer programme GIES (General Intake Estimation System) (99).

The Meal IQ was validated on the 254 calculated meals for its ability to assess dietary quality. First, the single components in the Meal IQ were tested to examine if the components correlated with the nutrient concerned, if number of fat, saturated fat, starchy, and whole grain units correlated with respectively grams of fat, saturated fat, carbohydrate, and dietary fiber. The correlation between fat units subtracted from starchy units and percentage of energy of total fat was also assessed, and furthermore the score of the snack component was compared to the percentages of energy from added sugar in the meals. Then, the Meal IQ score was estimated from the weighed food records of the lunches and validated against the calculated nutrient content of these meals.

3.3 Statistical analysis

In all statistical analyses significance level of 5% was applied. All reported P values were based on two-sided hypotheses. Statistical analyses were carried out using the SAS statistical software package (version 9.2, SAS Institute Inc., Cary, NC, USA).

3.3.1 Intervention study (paper III)

<u>Multilevel analysis</u>

We applied a multilevel statistical model to assess the effect of the school food programme on the Meal IQ score. The Meal IQ score were measured as repeated measurements for the same group of children at baseline, 1st follow-up and 2nd follow-up. The analyses were conducted on the differences of the Meal IQ score compared to baseline by using the following model:

$$y = \mu_0 + b + gr + t + in + s + ge + k + t*b + t*gr + t*in + t*s + t*ge + t*k + gr*in*t$$

Where *y* is the response variable (the difference in Meal IQ score relative to baseline value), μ_0 is the intercept (over all mean), *b* is the BMI value at baseline, *gr* represent the grades (2nd and 3rd grades, and 5th and 6th grades), *t* represent the measurement times (1st follow-up and 2nd follow-up), *in* represent two groups (intervention and control (intervention is the school meals)), *s* represent the social status, *ge* represent the gender, *k* is the Meal IQ score at baseline, *t*b, t*gr, t*in, t*s, t*ge, and t*k* represent the two-way interactions with the time, *t, and gr*in*t* the three-way interaction-term.

To take into account the hieratical structure of the data the model given above, in addition to the deterministic variables, included a number of stochastic variables which took into account the clustering of children within schools and classes and the repeated measurements of the same child. Thus the following structure was included in the model:

$$SC(IN),\ C(SC*IN),\ IP\,(SC*C*IN)$$

Where *SC* represent the schools and is nested with intervention (*IN*), *C* represent the classes and is nested with school and intervention, and *IP* represent a personal index for each child participation in the study and is nested with school, class, and intervention.

The two-way interaction terms were included in the model in order to test whether the development in the mean changes in Meal IQ score were parallel over time e.g. in intervention and control schools (*t*in)*.

Contrasts were constructed from the fitted model in order to test the particular hypothesis: if there was a significant mean change in the quality of dietary intake between children at the intervention schools having either free school meals (T2) or paid school meals (T3) compared to the children at the control schools having packed lunches. The estimated mean change values in the contrast were adjusted for other of the relevant factors in the model.

Baseline study

Before conducting multilevel analyses to examine the effectiveness of the intervention on the dietary quality of the lunches, preliminary analyses were done to determine whether children began the intervention with differences in age, sex, BMI, social back ground of the families, and dietary quality of their packed lunches brought from home. These baseline studies were carried out for the data measured at the time T1.

3.3.2 Digital photographic method (paper I)

5^{th} and 95^{th} percentiles are presented because of the non-normally distribution of the data. The Wilcoxon's signed-rank test was used to analyse the difference in dietary components and the Meal IQ assessed by the DPM and the weighed food. Spearman's correlation coefficient between the selected dietary components and the Meal IQ estimated from the digital images and from the weighed foods were assessed. Classification in quartiles of the estimated components and the total score of Meal IQ was done. Gross misclassification was defined as classification in the opposite quartile when observed in the highest and lowest quartile. Bland-Altman analyses were used to test the agreement between the continuous variables (fruit, vegetables, fish and the Meal IQ score) assessed from the digital images and the weighed foods. The limits of agreement were defined as two times the corrected standard deviations of the differences above and below the mean (100).

To determine inter-rater reliability of the DPM, a weighted kappa statistic was calculated for each of the dietary components and the Meal IQ. To conduct the kappa statistics on the continuous components and the Meal IQ, the variables were divided into 10 groups according to percentiles.

In the analysis specific for fruit, vegetables and fish, the meals not containing the food item were excluded in both the validity and reliability testing.

3.3.3 Meal Index of dietary quality (paper II)

Correlation coefficients between the estimated components and the objective measures were assessed to examine if the selected components in the Meal IQ reflected the nutrients of concern. Spearman's correlation coefficient was used while the data on dietary intake were not normally distributed (101). The estimated components were classified into quartiles. Gross misclassification was defined as classification in the opposite quartile observed in the highest and lowest quartile. Correlations between the Meal IQ score and the calculations of the nutrient content were assessed. The sample was divided into four categories according to the total Meal IQ score; and mean values of energy and nutrient content of the meals were compared by analysis of variance, after testing for equality of variances or using Kruskal-Wallis test. Bonferroni correction was used to account for increase in type I error due to multiple comparisons. Linear trends across the categories were tested by modelling the score as a continuous variable in the model and testing for model reduction.

4. Results

This chapter summarizes the findings from the three papers included in the present PhD thesis. Additional a few unpublished results are presented.

4.1 Effect of the school food programme (paper III)

4.1.1 Baseline characteristics of the children

The characteristics of the participants in the intervention schools and the control schools at baseline are described in Table 4.1 for all children and separate for the two groups (2^{nd}-3^{rd} and 5^{th}-6^{th} grades).

The mean age of children at baseline was 9.65 years in the intervention schools and 9.73 years in the control schools. Overall there was no difference in age of the groups but a statistical difference was found in the youngest age group ($P<0.0001$) due to more 3^{rd} grade children in the control group. At baseline no other differences, in gender, BMI, social background or Meal IQ, were found between the intervention group and the control group (Table 4.1).

4.1.2 Intervention effect on dietary quality of lunch consumed

The study population consisted of in total 984 children. Because the response variable is the difference in Meal IQ score relative to baseline value only the school children participating at baseline were included in the analyses. At baseline (T1) 966 children participated of these 951 and 936 participated at the 1^{st} follow-up (T2) and the 2^{nd} follow-up (T3), respectively. During the three measurement periods we measured 2853 times on a child (966+951+936), in 2431 cases we collected all 3 meals from the school child, 341 times we photographed 2 lunch meals and in 81 cases data on one lunch meal was obtained. In total data on 8056 lunch meals were included in the analysis, prior to this 146 lunch meals were excluded because data at baseline was not collected and three lunch meals were excluded from the analyses because consensus between the analysts was not reached about the food items on the digital images. Figure 3.1 describes the flow of the schools, participating school children and collected meals which are included in the statistical analyses.

Table 4.1: Characteristics and quality of dietary intake (Meal Index of dietary quality) of packed lunches in school children in the 2nd-3rd and 5th-6th grades and as a total at baseline

	Children in the 2nd and 3rd grades			Children in the 5th and 6th grades			All children		
Characteristics	Intervention	Control	P-value	Intervention	Control	P-value	Intervention	Control	P-value*
Age (years) (mean (SD))	8.23 (0.66)	8.46 (0.66)	<0,0001***	11.27 (0.61)	11.35 (0.71)	0,228	9.65 (1.65)	9.73 (1.59)	0.473
	n=237	n=245		n=209	n=193		n=446	n=438	
Gender (girls/boys) (% girls)	118/122(49.2%)	111/135(45.1%)	0,372	116/126(47.9%)	106/132(44.5%)	0,456	234/248(48.5%)	217/267 (44.8%)	0.248
	n=240	n=246		n=242	n=238		n=482	n=484	
BMI (kg/m^2) (mean (SD))	17.3 (2.3)	17.5 (2.7)	0,444	19.3 (2.9)	19.4 (3.4)	0,622	18.3 (2.8)	18.4 (3.2)	0.484
	n=237	n=242		n=237	n=231		n=474	n=473	
Social class‡ (numbers)									
I	15	18	0.662	14	21	0.234	29	39	0.248
II	4	4	0.972	10	10	0.971	14	14	0.991
III	78	94	0.363	87	85	0.970	165	179	0.538
IV	104	92	0.385	73	75	0.816	177	167	0.620
V	22	21	0.823	15	8	0.165	37	29	0.333
VI	15	7	0.107	25	24	0.936	40	31	0.295
VII	0	2	0.163	4	6	0.514	4	8	0.254
VIII	0	0	-	0	1	0.314	0	1	0.319
Missing information	2	8	0.066	14	8	0.225	16	16	0.991
Meal IQ (mean (SD))	11.6 (4.2)	11.9 (4.7)	0,345	11.0 (5.317)	11.2 (5.4)	0.4855	11.3 (4.8)	11.5 (5.1)	0.241
	n=695†	n=702†		n=667†	n=659†		n=1362†	n=1361†	

*P-value based on t test statistic, p-value for comparison of proportions are based on chi-square statistic
†**N**umber of meals
‡ Coded after the Danish Occupational Social Class (DOSC) (96)

The development of the changes in the dietary quality of the lunch consumed, expressed by the fitted Meal IQ values, in the intervention and control schools at baseline, 1st and 2nd follow-up are illustrated in Figure 4.1. To investigate if there was a significant effect of the intervention on the development of the quality of dietary intake at lunch at the 1st and 2nd follow-up an interaction-term between group (intervention/control) and time was included in the analyses. Overall, a significant different development over time was found for the intervention group compared to the control group ($P<0.0001$) (Table 4.2). At 1st follow-up, where the free school meals were served, children in the intervention schools had a significantly improved dietary quality of the lunch consumed relative to children in the control schools ($P=0.004$). At 2nd follow-up no significant difference between the dietary quality of lunch consumed in the intervention and control schools was found ($P=0.343$).

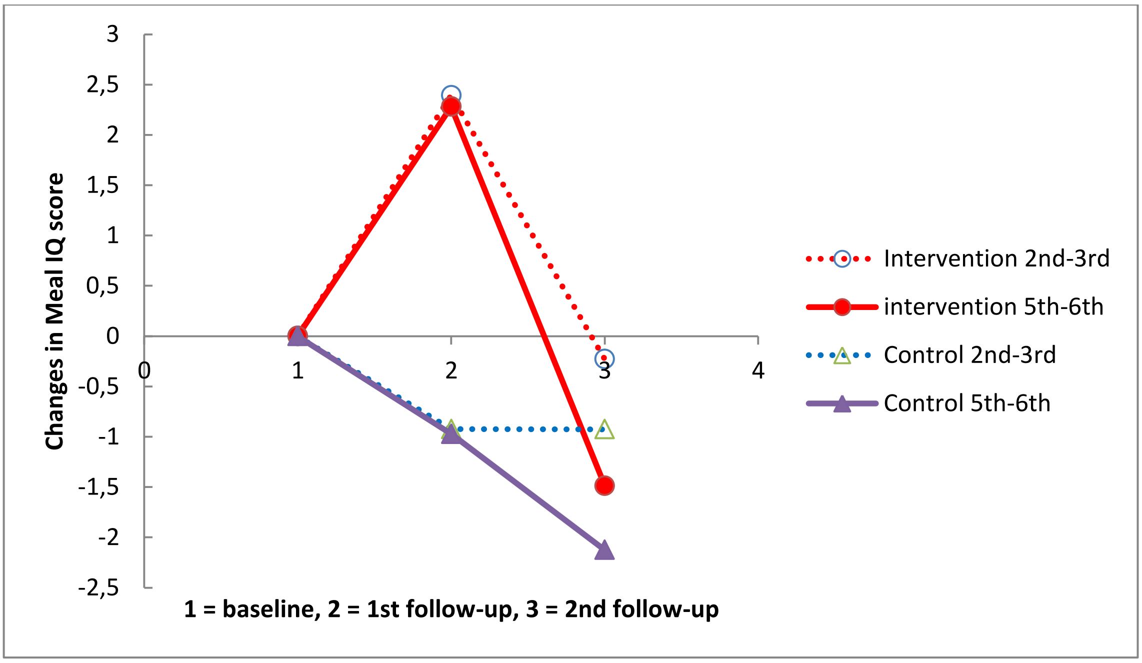


Figure 4.1: Comparison of changes in Meal IQ score between school children on intervention and control schools in 2nd-3rd grades and 5th-6th grades

The dietary quality of the packed lunches consumed at baseline was significant different between school children in the 2nd-3rd grades and 5th-6th grades; a higher mean Meal IQ score was found in the youngest age group. The mean (SD) Meal IQ score was 11.7 (4.5) for school children in the 2nd-3rd grades and 11.1 (5.4) for 5th-6th grades school children. Furthermore, a significant interaction between time and grade was found ($P<0.0001$) (Table 4.2) indicating a different development in changes in dietary quality over time depending on whether the school children went to the 2nd-3rd grades or the 5th-6th grades (Figure 4.1).

The three-way interaction-term (time x intervention x grade) however, was non-significant (P=0.083), indicating that there was no statistical different effect of the school food programme at T2 or T3 between children in the 2nd-3rd grades and 5th-6th grades. The differences between the age groups in the intervention group (0.042) seen in Figure 4.1 at time T3 is thus not due to the accessibility of school meals. And as Figure 4.1 illustrates, the same difference between age groups was found in the control group (P=0.001).

Table 4.2 shows the P-values and the parameter effect estimates of the explanatory variables significantly associated with the change in dietary quality for the final model.

Table 4.2: Explanatory variables from the main analysis of effects on changes in dietary quality. The effect estimate and standard error (SE) of all parameters is given together with the P-value (n=5333).

Symbols	Effects	Estimate (SE)	P-value*
μ_0	Intercept	6.99 (0.54)	<0.0001
K	Meal $IQ_{baseline}$	-0.66 (0.03)	<0.0001
In	+ intervention	3.13 (0.56)	0.016
	-intervention (control group)	0	
Gr	Grade (5^{th}-6^{th})	-0.55 (0.30)	<0.0001
	Grade (2^{nd}-3^{rd})	0	
T	Time (T_3)	-0.93 (0.48)	<0.0001
	Time (T_2)	0	
*k*t*	Meal $IQ_{baseline}$ x time (T_3)	0.08 (0.04)	0.026
	Meal $IQ_{baseline}$ x time (T_2)	0	
*in*t*	Intervention x time (T_3) (intervention group)	-2.70 (0.28)	<0.0001
	Intervention x time (T_2) (intervention group)	0	
	Intervention x time (T_3) (control group)	0	
	Intervention x time (T_2) (control group)	0	
*t*gr*	Time x grade (T_3) (5^{th}-6^{th})	-1.17(0.28)	<0.0001
	Time x grade (T_3) (2^{nd}-3^{rd})	0	
	Time x grade (T_2) (5^{th}-6^{th})	0	
	Time x grade (T_2) (2^{nd}-3^{rd})	0	

*P-value for Type 3 tests for fixed effects

More children in the 5th and 6th grades did not bring or skipped a lunch meal compared to the children in the 2nd and 3rd grades. Table 4.3 illustrates the percentage of children in the 2nd-3rd grades and the 5th-6th grades divided into the intervention and control group who always, sometimes or never eat a lunch meal in the week of measurement at baseline or the two following measurements.

Table 4.3: Prevalence of children in 2^{nd}-3^{rd} grades and in the 5^{th}-6^{th} in the intervention and control schools who always, sometimes or never eat lunch at baseline (T1), 1^{st}(T2) and 2^{nd} follow-up (T3)

			Meal		
Time	Group/grade	n	Always lunch % (Δ)*	Sometimes lunch % (Δ)*	Never lunch % (Δ)*
T1	Intervention group				
	2^{nd}-3^{rd} grades	240	98.33 (ref.)	1.67 (ref.)	0 (ref.)
	5^{th}-6^{th} grades	242	79.34 (ref.)	18.18 (ref.)	2.48 (ref.)
	Control group				
	2^{nd}-3^{rd} grades	246	97.15 (ref.)	2.44 (ref.)	0.41 (ref.)
	5^{th}-6^{th} grades	238	76.89 (ref.)	18.91 (ref.)	4.20 (ref.)
T2	Intervention group				
	2nd-3rd grades	243	98.77 (0.4)	1.23 (0.4)	0 (0.0)
	5th-6th grades	241	92.95 (13.6)	7.05 (-11.1)	0 (-2.5)
	Control group				
	2nd-3rd grades	247	92.71 (-5.4)	7.29 (5.85)	0 (-0.4)
	5th-6th grades	243	65.43 (-11.5)	30.45 (11.5)	4.12 (-0.1)
T3	Intervention group				
	2nd-3rd grades	239	96.65 (-1.7)	3.35 (1.7)	0 (0.0)
	5th-6th grades	240	67.50 (-11.8)	24.58 (6.4)	7.92 (5.4)
	Control group				
	2nd-3rd grades	250	89.60 (-8.6)	9.60 (7.2)	0.80 (0.4)
	5th-6th grades	241	53.94 (-22.9)	34.02 (15.1)	12.03 (7.9)

*Difference relative to baseline

This aspect could explain some of the different effect of age. When the effect of the skipped meals (skip a meal yes/no/sometimes) was accounted for in the model as a new explanatory variable the variable *gr* (grade) was no longer significant and was taken out of the model since most of the reason for a difference between the grades was explained by this 'new' variable.

In the main model the observations of skipped lunch meals were included. If a child participated at the day of measuring and did not eat a meal in the lunch break the assigned Meal IQ value was 0. Sub-analyses where the skipped meals were excluded were conducted. These analyses showed like the main analyses that a significant difference was shown between the intervention and control groups at 1^{st} follow-up (P=0.0006) and no difference was found at the measurement time for the 2^{nd} follow-up (P=0.553).

During the study and trough the academic year more school children did not always eat a lunch meal. In Figure 4.2 this development is illustrated. This is seen among the children at the control schools and especially among the children in the 5^{th} and 6^{th} grades but also among the younger age group. In the intervention group this change in always having lunch meals is positive at the 1^{st} follow-up where the school meals are free and in the 2^{nd} follow-up the development follows the one seen in the control group, where the change is negative, especially among the oldest school children.

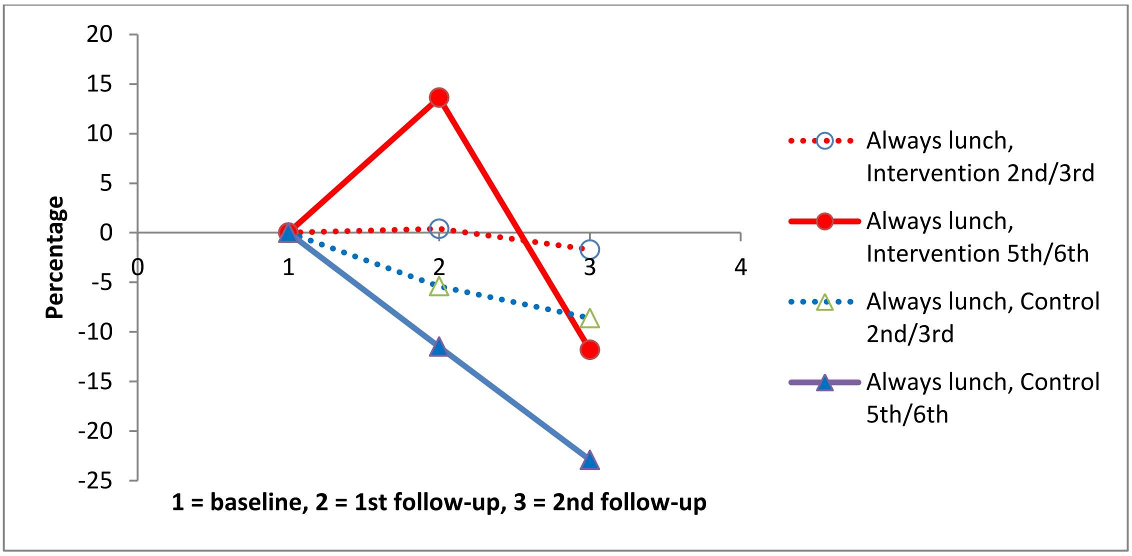


Figure 4.2: Changes in always having lunch meals between school children on intervention and control schools in 2nd-3rd grade and 5th-6th grade

The mean (SD) and the range of the Meal IQ score is for the packed lunches respectively 11.8 (4.1) and 0-26 and for the school meals the mean (SD) is 13.9 (3.4) and the range goes from 2-24. Histograms of the distribution of the Meal IQ score from the intake of packed lunches and school meals are shown in Figure 4.3.

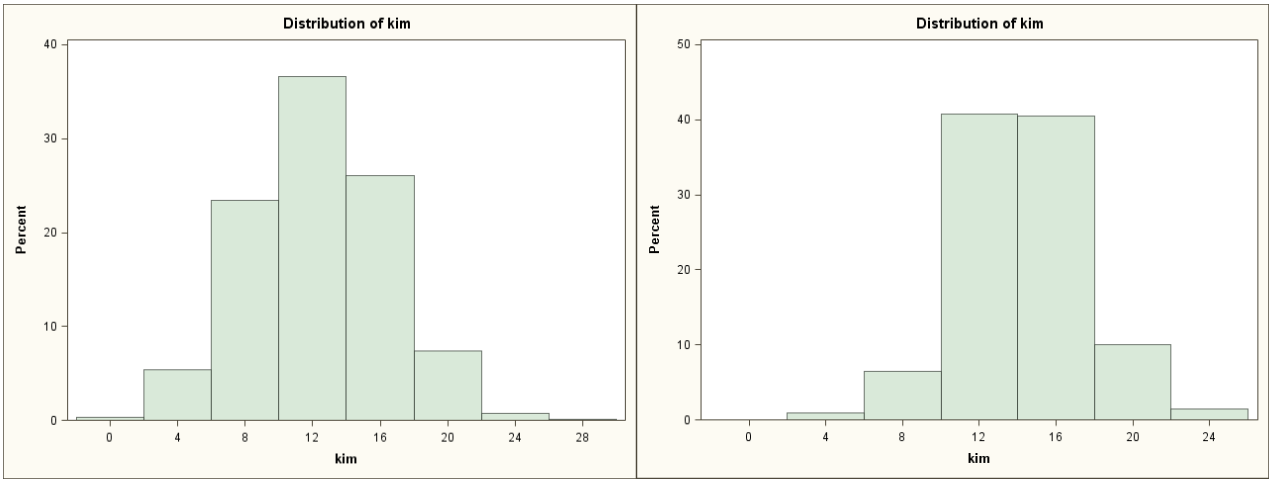


Figure 4.3: Distribution of Meal IQ score in packed lunches (left) (n=6097) and school meals (right) (n=1340)

4.1.3 Sustainability of the school food programs

At the 2nd follow-up the school meals on the interventions school were no longer free. Only at two of the four intervention schools the school food programme continued beyond the period of free school meals and at one of the schools the school food programme only continued partly. At these two schools respectively 21% and 6% of the lunch meals consumed were school meals. On the school where the school food programme had continued 78% of the children said that they used the possibility of buying a school meal and on the other school where it was only possible to buy a school meal some of the days 21% answered that they used this option. More than half of the school children buying school meals do this one day at the week or lesser. Of those children who used the possibility of buying a school meal 90% were satisfied or very satisfied with the school meals, the last 10% were neither satisfied or not.

4.2 Validity and reliability of the digital photographic method (paper I)

The single components of the Meal IQ were assessed from the digital images and the weighed foods of the lunches. In Table 4.1 the results of the comparison of the digital images and the objective weights are shown. Besides the medians and the 5th and 95th percentiles of the dietary components and the total score of the Meal IQ assessed from the two methods the results from the Wilcoxon's signed-rank test, the Spearman's correlation coefficients and the classification in quartiles is shown. No statistical difference between fish, fat, starchy units, whole grain units and the Meal IQ score assessed from the digital images and the weighed foods. Fruit, vegetables and saturated fat units were significantly different, though the difference between the saturated fat units was borderline significant (P=0.046). The correlation coefficients between the dietary components and the Meal IQ estimated from the digital images or the weighed foods ranged from r=0.89 to r=0.97. In 98% of the meals the starchy units, estimated from the digital images or the weighed foods, were classified in the same or adjacent quartile. For fruit, vegetables, fish and whole grain units, and total score of Meal IQ this was the case for 100% of the meals. Gross misclassification was not found for any of the dietary components or the total Meal IQ score.

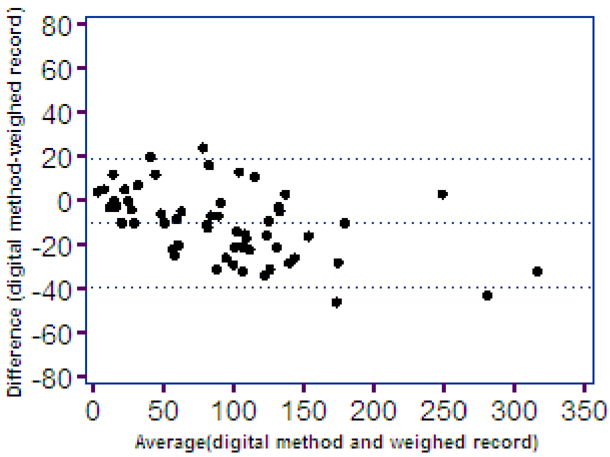
Table 4.4: Dietary components and the Meal IQ score estimated from weighed foods and digital images (median and 5 and 95 percentiles). P-values for Wilcoxon's signed-rank test and cross-classification and correlation analysis between values estimated by the digital and the weighed record methods

Components	N	Actual content from weighed foods Median (P5, P95)[§]	Estimated content from digital images Median (P5, P95)[§]	P-values for differences	Classified into same/same or adjacent quartile (%)	Correlation coefficients Spearman[$]
Fruit g	67	87 (13;195)	80 (15;174)	<0.0001	84/100	0.96
Vegetables g	130	52 (10;141)	48 (10;125)	0.0003	76/100	0.96
Fish g	21	24 (11;50)	22 (7;52)	0.061	81/100	0.89
Fat units	191	1.5 (0;4.5)	1.5 (0;5)	0.086	79/99	0.93
Saturated fat units	191	1.5 (0;4)	1.5 (0;4)	0.046	72/99	0.91
Starchy units	191	1.75 (0.5;3.5)	1.75 (0.5;3)	0.234	74/98	0.89
Whole grain units	191	1 (0;2.5)	1 (0;2)	0.062	87/100	0.96
Meal IQ score	191	16 (5;20)	16 (6;20)	0.339	80/100	0.97

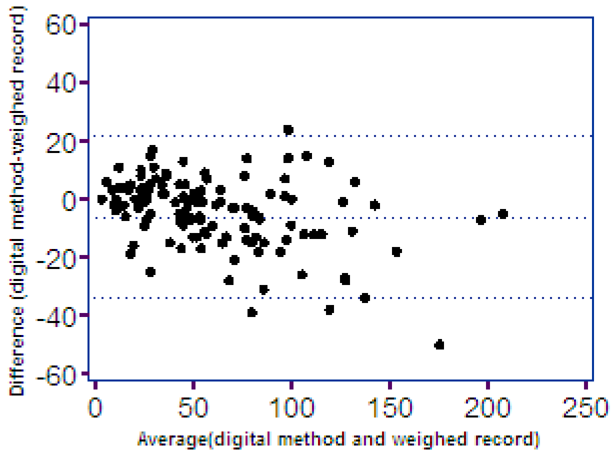
[§]P5: 5th percentile; P95: 95th percentile
[$]All Spearman's correlation coefficients were significant, P<0.001

The continuous dietary variables (fruit, vegetables and fish) and the Meal IQ score estimated from the digital images and from the true weights were also compared using Bland-Altman plots (Figure 4.1). The bias was -4.27g with the 95% limits of agreement between -29.4 and 20.8g. Estimation of the amount of vegetables from the DPM had a bias of -6.19g compared with the weighed food record, and 95% limits of agreement of -34.5 and 22.2g. When compared with the true amount of fish, the DPM showed a bias of -2.33g and 95% limits of agreement from -14.7 to 10.0g. The mean of the difference of the Meal IQ score between the methods was 0.07 and the 95% limits of agreement were ±2.33 around the bias.

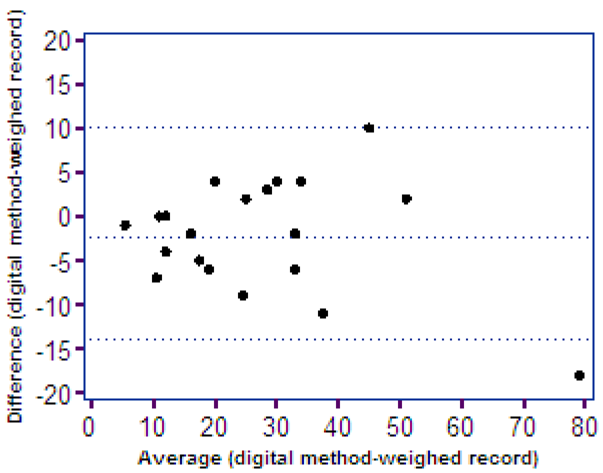
Fruit (g)



Vegetables (g)



Fish (g)



Meal IQ

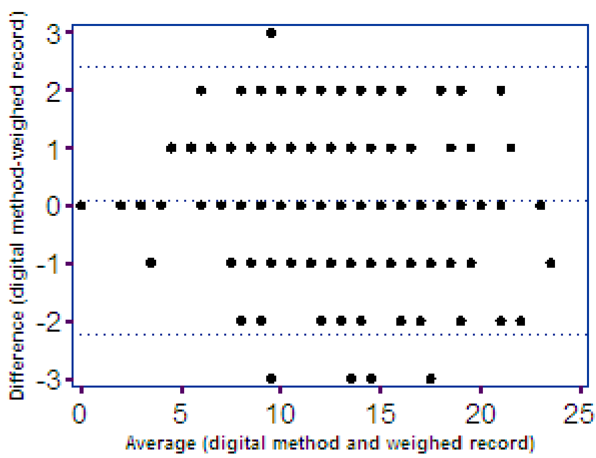


Figure 4.5: Bland-Altman plots of agreement on the weight of fruit (n=67), vegetables (n=130), fish (n=21), and score of Meal IQ (n=191) obtained from the digital photographic method versus the weighed foods. The x-axis shows the mean of the two methods and the y-axis shows the difference between the digital photographic method and the weighed foods. The middle line denotes the mean difference (bias), whereas the top and bottom lines show the upper and lower limits of agreement.

4.2.1 Reliability testing of the digital photographic method

The reliability testing of the estimated dietary components of the Meal IQ and the Meal IQ score using the DPM showed kappa coefficients that ranged from 0.59 (starchy units) to 0.82 (fruit) across all components. The Meal IQ yielded a kappa coefficient of 0.76.

Table 4.5: Inter-rater reliability measures of the digital photographic method using weighted kappa test statistics (n=191)

	Inter-rater Reliability	
Components in Meal IQ	Kappa	95 % CI
Fruit	0.82	0.76-0.88
Vegetables	0.79	0.75-0.83
Fish	0.70	0.60-0.79
Fat units	0.69	0.63-0.74
Saturated fat units	0.69	0.64-0.75
Starchy units	0.59	0.52-0.66
Whole grain units	0.76	0.68-0.84
Presence of snack products	0.80*	0.69-0.91
Meal IQ	0.76	0.72-0.81

*Simple Kappa Coefficient

4.3 Validation of the Meal Index of dietary Quality (Meal IQ) (paper II)

4.3.1 Correlation between the Meal IQ components and calculated nutrient content in the lunch meals

The first step was to assess if the single dietary components of the Meal IQ did express the specific nutrient. Vegetables, fruit and fish are food items and are shown directly in the weighed food records, but it is different when it comes to total fat, saturated fat, whole grain/potatoes and snack products estimated from respectively starch units minus fat units, saturated fat units, whole grain/potatoes units and the snack product score. All the different units were estimated from the weighed food records and validated against the relevant calculated nutrient content (Table 4.6). The component estimating fat content was highly correlated to percentage energy of fat (r=-0.77), also illustrated in Figure 4.6. Numbers of saturated fat units were correlated to percentage energy of saturated fat (r=0.76). The number of whole grain units was correlated to dietary fiber (r=0.56); and the snack component was correlated to added sugar in the meals (r=0.57).

Table 4.6: Correlations between the calculated nutrient content of the meal components and the nutrient components of the Meal Index of dietary Quality (Meal IQ) (n=254)

Components		Correlation coefficients	
Calculated from weights of ingredients in the meals	Estimated values	Spearman	P-values for correlation
Fat (E%)	Starch units – fat units	-0.77	<0.0001
Saturated fat (E%)	Saturated fat units	0.76	<0.0001
Dietary fiber (g)	Whole grain and potatoes units	0.56	<0.0001
Added sugar (E%)	Snack product score	0.57	<0.0001

E%: percentage of food energy

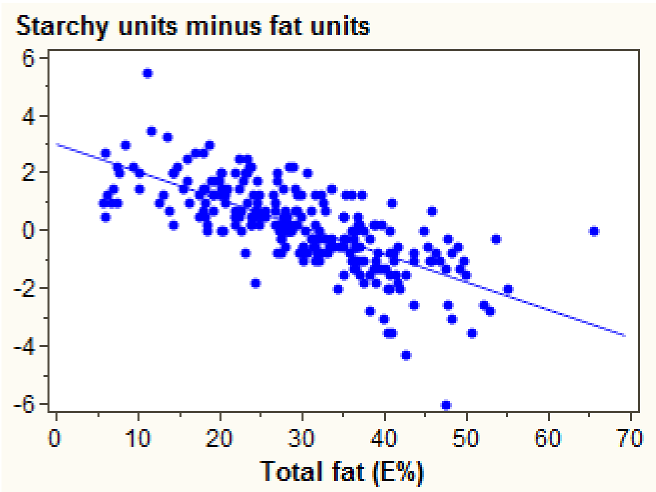


Figure 4.6: Calculated number of starchy units minus fat units compared with the percentage energy from total fat (E%) (r=-0.77)

The classification which was also done to examine the individual components of the Meal IQ ranged from 91% (whole grain units versus fiber) to 98% (starch units in snack product versus added sugar). Gross misclassification was found in one of the 254 cases for the components measuring added sugar, saturated fat, and total fat; and for the whole grain score correlated with fiber, misclassification was found in 2% of the meals.

4.3.2 Correlation between the Meal IQ score and nutrient content

Table 4.4 illustrates the Spearman's correlation coefficients between the score for Meal IQ and the nutrient content of the nutrient-calculated meals, the P values for the correlations, P values for trend across the

Meal IQ categories and the P values for differences between the categories. A higher Meal IQ score was significantly associated with a lower intake of total and saturated fat and sugar and a higher intake of dietary fiber, fish, fruits, vegetables and various vitamins and minerals. The correlation coefficients varied between dietary components and were highest for energy density (r=-0.61) and lowest for energy (r=0.04) where no association was measured. The linear trend was highly significant for the energy percentage for fat and saturated fat, dietary fiber, vitamin E, vitamin K, vitamin B_6, folic acid, vitamin C, fruits and vegetables. There was also a trend for vitamin A (P=0.027). The result of the analysis for trend showed no significance across the Meal IQ score for energy, energy density, energy percentage from carbohydrate and added sugar, calcium, iron and fish. The P values for the ANOVA analysis showed a significant difference between the Meal IQ score categories for all the nutrient and food groups except energy and vitamin A, and after Bonferroni correction, there was no difference between the categories for calcium either.

Table 4.7: Energy and nutrient content of the meals by categories, according to the total score of the Meal Index of dietary Quality (Meal IQ) (n=254).

	Meal IQ score											
	(0-7 points) n=26		(8-13 points) n=102		(14-19 points) n=105		(19-28 points) n=21					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P-values for ANOVA or Kruskall-Wallis tests	Spearman's correlation*	P-values for correlation	P-values for trend
Energy (kJ)	1549	631	1350	563	1358	568	1710	570	0.054	0.04	0.484	NS
Energy density (kJ/100g)	1032^{a}	201	818^{b}	256	595^{c}	180	552^{c}	121	<0.0001	-0.61	<0.0001	NS
Fat (E%)	39.8^{a}	6.53	33.7^{b}	10.1	24.6^{c}	9.17	22.1^{c}	6.92	<0.0001	-0.58	<0.0001	<0.0001
Saturated fat (E%)	15.8^{a}	5.04	11.5^{b}	4.63	7.00^{c}	3.96	5.30^{c}	3.00	<0.0001	-0.63	<0.0001	<0.0001
Carbohydrate (E%)	46.7a	7.68	49.9^{a}	11.4	60.3^{b}	10.5	61.5^{b}	9.38	<0.0001	0.52	<0.0001	NS
Added sugar (E%)	3.79^{a}	5.69	1.06^{b}	2.12	0.49^{b}	1.41	0.08^{b}	0.14	0.001	-0.22	<0.0001	NS
Fiber (g/MJ)	3.23^{a}	1.56	4.26^{a}	1.75	5.75^{b}	1.98	6.41^{b}	1.42	<0.0001	0.54	<0.0001	<0.001
Vitamin A (µg RE)	225	391	262	291	322	325	421	352	0.10	0.13	0.034	0.027
Vitamin D (µg)	0.23^{a}	0.21	0.22^{a}	0.36	0.19^{a}	0.44	0.83^{b}	1.26	0.0001	-0.13	0.045	NS
Vitamin E (mg)	0.88^{a}	0.61	1.19^{a}	1.06	1.42^{ab}	1.04	1.93^{b}	1.01	<0.0001	0.32	<0.0001	<0.0001
Vitamin K (mg)	2.36^{a}	3.85	10.3^{ab}	15.9	14.1^{b}	14.0	24.6^{c}	13.1	<0.0001	0.49	<0.0001	<0.0001
Vitamin B_6 (mg)	0.19^{a}	0.12	0.24^{ab}	0.15	0.27^{b}	0.13	0.39^{c}	0.14	<0.0001	0.30	<0.0001	<0.0001
Folic Acid (µg)	33.1^{a}	26.0	54.1^{b}	31.4	68.6^{c}	37.3	90.0^{d}	29.4	<0.0001	0.38	<0.0001	<0.0001
Vitamin C (mg)	9.27^{a}	6.38	15.5^{a}	17.8	25.4^{b}	21.7	26.5^{b}	16.4	<0.0001	0.47	<0.0001	<0.0001
Calcium (mg)	128^{a}	151	83.5^{a}	82.6	83.4^{a}	62.7	122^{a}	110	0.023	0.09	0.117	NS
Iron (mg)	2.15^{a}	1.55	1.95^{a}	0.95	2.16^{a}	1.12	3.36^{b}	2.15	0.001	0.19	0.003	NS
Fruits (g)	0.58^{a}	2.94	8.03^{a}	28.7	41.5^{b}	67.8	52.6^{b}	55.2	<0.0001	0.50	<0.0001	<0.0001
Vegetables (g) ✝	5.00^{a}	11.3	41.3^{b}	50.1	64.6^{c}	48.9	90.6^{c}	42.1	<0.0001	0.48	<0.0001	<0.0001
Fish (g)	1.08^{a}	5.49	0.90^{a}	6.06	4.40^{a}	14.0	21.8^{b}	28.2	<0.0001	0.36	<0.0001	NS

E%, percentage of food energy

[a,b,c,d] Values within a row with different superscript letters are significantly different (P<0.05) after Bonferroni correction for multiple comparisons.

* Spearman's correlation coefficient analyses are made using the 28-classed score.

✝ Exclusive potatoes

5. Discussion

This PhD thesis builds upon the evaluation of the school food project which the Danish Food Industry Agency announced in 2007. The study was designed and evaluated and new methods were developed for the purpose. This section presents a general discussion of some of the topics that were not addressed in the papers I-III or topics that could be further discussed.

5.1 Digital photographic method used for measuring of dietary intake (paper I)

We found the standardized DPM to be valid and reliable for assessing dietary quality of packed lunches brought from home. The validation showed no statistical difference between the Meal IQ score assessed from the DPM or from the weighed foods. The Bland-Altman plot showed a small bias (0.07), and the limits of agreement were tight to suggest good agreement between the two methods (-2.26 to 2.40). All indicating the Meal IQ to be a suitable tool for the evaluation of an intervention study.

Most of the components (fish, fat, starch, whole grain) of the Meal IQ were estimated without differences between the test and reference method. Differences were found for fruit and vegetables. The Bland-Altman analyses showed limits of agreement on the same level as others have reported (102). A tendency toward underestimation of high amount of fruit and vegetables was found, and further analyses showed that this problem did not exist for amounts beyond 85 g of vegetables and 115 g of fruits. Thus the tendency to underestimate vegetables and fruits does not affect the Meal IQ score, as levels beyond 75 g of respectively fruit and vegetables are easier to estimate correct. Others have also reported underestimation using the DPM (74,102-104).

The DPM has been used in varying settings and on different target groups and types of meals, and others have also found the method to be valid and reliable (68-71,102). The method has been applied earlier for assessment of school meals (70,71,105,106) but not for assessment of packed lunches brought from home. The findings of this study indicate that the standardised DPM we used is valid and reliable when used to assess dietary intake from packed lunches.

Different approaches have been used for validation of the DPM. Martin et al. (71) validated the DPM against the BMI of the children, Williamson et al. (69) used the visual estimation technique to validate the method and in another study Williamson et al. (68) compared the DPM with weighed foods. We also used weighed foods as reference method for the validation study, which is a more objective method than reference methods which rely on estimation, and BMI depends on a lot of other aspects than the lunch.

The DPM has mainly been applied to single meals rather than whole diets, though it would be interesting to investigate the effect of implementing a school food programme on the entire diet. This would complicate the use of the DPM. Digital images of food selection and plate waste are easily captured in settings as class rooms and cafeterias. If the entire diet has to be measured, data have to be collected under free-living conditions which will require that the respondents capture the digital images themselves. It is likely that these circumstances could affect the possibility of estimation errors due to lower quality of the digital images and a decreased standardization of the method. The involvement of the respondent is thereby increased, which besides the quality of data could affect the compliance negatively.

Some studies have examined the possibility on assessing food intake among free-living people. Lassen et al. (102) have used a DPM under free-living conditions in private homes where the participants were instructed on how to capture digital images on their evening meals to standardise the procedure. Lassen et al. found the DPM to be valid and feasible for this purpose. Martin et al. (74) developed a remote food photography method with the purpose to measure energy intake in free-living conditions. A camera-equipped cell phone was used to capture images of food selection and plate waste. The images were sent to the researchers over the wireless network for food intake estimation. This method has proved to be valid (107).

One of the important advantages of using the DPM is the limited burden of the respondent, which is very essential when measuring the dietary intake among children. Instead the burden is on the researcher and especially the portion estimation and dietary evaluation is time consuming and a weakness of the method. We developed an index (Meal IQ) to do the method as cost-effective as possible. Automation of the portion size estimation may do the DPM more effective. Research indicates that future advancements of using technology for dietary assessment are possible (108-112). Martin et al. (112) have developed a semi-automated computer imaging application to estimate food intake based on pictures captured by free-living people by a camera-equipped smartphone with wireless data transfer capabilities. The automated system estimates the food type and gram amount in each image, which is afterwards evaluated by a dietitian. Colour features are used for recognition of different foods. Weis et al. (109) have developed a "Food Intake Visual and voice Recognizer". A smartphone is used to capture images of the food eaten. The types and amounts of food are identified by the system and a voice recognition software is utilized to automate the food list capture process and support queries to clarify food details. Future advancement of these systems is needed to improve the performance of the systems. Techniques used in other areas may also be used for future dietary assessment procedures. Development of systems for automatic visual recognition of produces has earlier been reported. Bolle et al. (111) developed a produce recognition system for supermarkets and grocery stores, where a colour camera is used to image the items. From the image multiple recognition clues such as colour, texture, size, shape and density (weight/area) can be extracted. Instead of manual identification of food items and portion size estimation the automation would make the DPM much more efficient and cost-effective, and possibly more accurate.

Several researchers have described the use of smartphones to capture digital images of food intake (74,104,109,113,114). Boushey et al. (115) found a strong preference for technology methods among children aged 11-15 years, compared to pen-and-paper records, which indicates that the smartphone can be appropriate for this target group. It is unknown how old children should be to use a smartphone for data collection. Research is needed to clarify this.

Taken into account the target group and the setup of the dietary intervention study with many participants and repeated measurements the DPM was an appropriate method for measuring the dietary intake. The elimination of bias regarding recall problems and portion size estimation is an advantage of the DPM and furthermore the minimal burden of the respondent made the method appropriate for the evaluation of the school food programme.

One limitation of the method is the time consuming step where the portion sizes have to be estimated, in this study amounts of grams of fruit, vegetables and fish and units of fat and starchy foods (including saturated fat and whole grain). This procedure puts some demands on the persons who are responsible for this and thus training is required. In the present study the reference material, developed for the estimation of weights and units, was found to be very supportive for the consistency of the estimation and has also increased the validity of the DPM. The packed lunches normally comprise open sandwiches (often on rye bread) with spread and cold sliced meat, sometimes with fruits and vegetables (4), often in relatively standardised portions which eases the estimation procedure. However, composite dishes may occur even in lunches brought from home and because recipes and product specifications (e.g. fat-reduced) are not available this complicated the estimation of such meals. We used data from GfK (Gesellschaft für Konsumforschung) Denmark (97) and from the Danish National Survey of Dietary Habits and Physical Activity (12) to obtain information on the dietary composition of composite dishes or products. The challenge connected with estimating mixed dishes when assessing dietary intake has been reported by others (68), however, among Danish school children composite dishes are not a big issue in packed lunches because they do not often occur.

One weakness of the present validation study was that the researcher who recreated the packed lunches from the 191 digital images also afterwards participated in the assessment of the quality of the dietary intake of these lunches. Due to limited ressources no other way was possible. However, this procedure could affect the demonstrated validity of the DPM. The procedures of recreating the packed lunches and the dietary assessment were not made in the same time period. Furthermore, the DPM was also found to be highly reliable indicating that others not participating in the recreation of the packed lunches estimate the weights and units with the same accuracy.

Recording error may occur using the DPM if the children after their lunch meal has been photographed eat each other's foods or switch food items. Another limitation could be if they forgot to have their leftovers photographed. We tried to eliminate this bias by giving the instruction that everybody's plate was supposed to be photographed with or without leftovers.

We validated the standardized DPM against weighed foods of packed lunches brought from home. In the sample we did not include school meals, which was not possible in this thesis due to time restraints. This can be perceived as a limitation. However, the DPM has earlier been validated on school meals and furthermore it is relatively easy to get information on the composition of school meals, because recipes are available and through them more information on the non-visual food items. Furthermore, the school meals are often standardised.

It is not known if the data collection procedure influences the food intake of the children. But if there is a research bias, it probably does not influence the data collection of the food intake from packed lunches and school meals differently and thus would not affect the overall results of the present study.

5.2 Meal Index of dietary Quality (paper II)

We developed the Meal IQ score to be an indicator of the overall dietary quality of lunch meals for school children. The Meal IQ was developed with the purpose to be simple, flexible with regard to the different types of meals, and it also had to be sensitive enough to measure relevant differences when children were having school meals instead of packed lunches.

We found the Meal IQ to be a valid and a useful evaluation tool for assessment of the quality of dietary intake of school meals and packed lunches brought from home in children aged 7-13 years. A higher total Meal IQ score was associated with higher dietary quality, thus a high Meal IQ score was correlated with lower contents of fat, saturated fat and added sugars, higher contents of dietary fiber, various vitamins and minerals and also fruits, vegetables and fish. Thus the association was not just shown for the Meal IQ score and the nutrient and food groups included in the index, but also with other nutrients, which suggests that the Meal IQ is a good indicator of the overall dietary quality.

Several statistical analyses were conducted for the validation of the Meal IQ. Correlation analyses are extensively used to validate dietary assessment methods, but correlation coefficients provide only a limited measure of the level of agreement between two methods (100) and should therefore not be used alone. Besides correlation analyses we used cross-classification, ANOVA and trend analyses. This approach where both ANOVA and trend analyses were conducted gave the opportunity to get more specific information on the association of the Meal IQ score and the calculated energy and nutrient content of the meals. A non-significant trend was found for added sugar and fish/vitamin D across the Meal IQ categories. The ANOVA analyses showed, after Bonferroni correction for multiple comparisons, a significant higher content of added sugar in the category for meals with the lowest Meal IQ score and the other categories with higher Meal IQ scores. A similar result was found for fish/vitamin D and the Meal IQ categories, but where the meals with the highest Meal IQ had a significantly higher amount of fish/vitamin D compared to the other categories. And opposite a linear trend across the Meal IQ categories for vitamin A was shown but in this case the result of the ANOVA analysis was non-significant. The content of vitamin A increases slightly with a higher Meal IQ score, but the variations are high and thus the ANOVA test was not significant.

Data were similar for the school meals and the packed lunches and the analyses were therefore combined. A single inconsistency was seen in the association regarding energy density and the Meal IQ of the two types of meals. The correlation coefficient between the Meal IQ and energy density of the packed lunches was significant ($r=-0.73$, $P<0.0001$) but for the school meals the Meal IQ and energy density the correlation coefficient was low ($r=-0.13$, $P=0.13$). Nutritionally, the school meals were more alike than the packed lunches and the variety in the energy density smaller, which may be the reason that we did not see a significant correlation but a linear trend was found. Besides, one of the school meals consisted of rice-pudding having a low Meal IQ score and a low energy density. When this atypical meal was excluded from the analyses the correlation between the Meal IQ score for the lunches provided by the schools and the energy density was increased from $r=-0.13$ to $r=-0.18$ ($P=0.07$). Correlation analysis should be used with caution, as the correlation coefficients are actually not very useful if a range in a true quantity in the sample is not very wide (100).

There are some challenges connected to the development of dietary quality indices; e.g. the ways of handling differences in energy intake (75-77). Many indices show a positive association between the score and total energy intake (81,85,90). We did not see this positive correlation between the Meal IQ score and the total energy intake. This should be considered as an advantage because the Meal IQ highly depends on dietary quality and not on the amount of energy. The development of an index encompasses dietary adequacy, variety, moderation, and balance and if nutrient adequacy is weighted more heavily than moderation the index score could be associated with total energy intake (116). But still it is important that school children get the amount of energy recommended for the lunch meal (13). This aspect should be taken into account in the future adaptation and development of the Meal IQ. Furthermore, the methodological issues concerning the scoring of each component and the weighting of each component when combining the variables into one measure need further investigation.

A limitation using the Meal IQ is the need for recipes and product specifications, especially when assessing the hot meals for which it might be difficult to assess the content of e.g. fat and amounts of vegetables.

5.3 Dietary effect of a school food programme (paper III)

In the main study we found that the mean change in the quality of dietary intake in the time tabled lunch break was improved at the 1^{st} follow-up where the school children were having a free school meal instead of a packed lunch brought from home. At the 2^{nd} follow-up only 7% of the meals at the intervention schools were school meals and there was no difference in the quality of dietary intake between the intervention and control group. Age was shown to be a significant explanatory variable ($P<0.0001$) and the two-way interaction term grade x time was also significant ($P<0.0001$) but the three-way interaction grade x time x intervention was not. Thus there was no difference in dietary effect between children in the 2^{nd}-3^{rd} grades and children in the 5^{th}-6^{th} grades neither at the 1^{st} follow-up nor at the 2^{nd} follow-up. The significant two-way interaction-term grades x time was due to a difference between age groups at T3 where the school meals were paid by the parents, but the same difference was found in the control group and did thus not depend on the accessibility of school meals, also illustrated by the non-significant three-way interaction-term. However, most of this difference in age could be explained by the many school children in 5^{th} and 6^{th} grades who did not bring a packed lunch and thus when we accounted for the effect of skipped meals in the model the effect of age was no longer significant.

In the main analyses we included the observations of the skipped lunch meals. Introducing a school food programme could ensure the availability or accessibility of a lunch meal for all children of diverse ethnic and socio-economic groups. Some of the dietary effect of a school food programme would be due to all children having a lunch and if we did not bring the information about the skipped meals into the analyses we would underestimate the effect of a school food programme. When we conducted the analyses without the observations of skipped lunch meals the main results were the same; there was a significant effect at 1^{st} follow-up but no effect when the school meals were paid. And thus the effect of the school food programme is not explained by the many skipped meals. The results clearly showed that the school food programme influenced the prevalence of children skipping meals among the school children in the 5^{th} and

6^{th} grades, where 93% always had lunch at 1^{st} follow-up where the lunch was free compared to 79% at baseline (packed lunches) and 68% at the 2^{nd} follow-up (paid school meals). It was also interesting that none of the oldest school children never skipped a lunch in the period with the free school meals. An important finding of the present study was that the school food programme resulted in a reduction of skipped meals when the school meals were free of charge.

It is possible that the dietary quality of the packed lunches could be influenced by the parents who knew about the investigation. We collected data on 3 consecutive days in a week at each of the 3 measurement periods. The first day at baseline, 1^{st} and 2^{nd} follow-up, only the principal and teachers of the school knew we were coming, but the school children and the parents did not know. However, when comparing the dietary quality of food intake of the first day with the 2^{nd} and 3^{rd} day this did not show any systematic statistical difference between the days when looking at all 3 measurement periods. However, at baseline there was a significant difference between the quality of dietary intake of the lunches measured at day one compared to the two following days, which were both better than the first day. At the 1^{st} follow-up there was a difference between day 1 and 3 where day 1 were scoring highest in the Meal IQ. A difference was also measured between day 2 and 3, but no difference between day 1 and 2. At the 2^{nd} follow-up there were no significant differences between the dietary quality intakes across the days. If we did the analyses separate for the intervention and control group there was no difference in the control group between the days at any of the 3 times for measurement. However the difference in the intervention group at baseline may indicate a bias as the parents might have changed the normal content of the packed lunches because of the investigation. However, this possibly overestimated quality of the packed lunches would not affect the overall result indicating that the lunch children eat from a school meal has a higher dietary quality than that from a packed lunch.

Thus, this study confirmed that the quality of dietary intake was higher in the school meals compared to the packed lunches brought from home as found in the many cross-sectional studies. The evidence of a cause-effect relationship established in this intervention study is higher than the evidence obtained from observation studies because we collected the data from the same children throughout the study. To our knowledge this is the first intervention study investigating the effect of substituting a packed lunch with a school meal in the same children. However, several school-based intervention studies that use dietary changes as primary or secondary outcome measures also demonstrate a dietary effect, i.e. several found an increase in intake of fruit and vegetables (117-124). Prell et al. (125) investigated fish consumption and found an increase of this food item due to the intervention. Some used fat as outcome measure and found that the intervention resulted in a decrease in intake of fat (105,126-130). Furthermore, some used other indicators of a healthy diet and showed a positive effect (131,132) and some of the interventions did not show any dietary improvement (133-135). This indicates that besides the present study several studies find a positive effect of using the school setting for some kind of dietary intervention.

We did not use the content of energy, nutrients or food groups as outcome measure but instead a Meal IQ developed and validated for the purpose. The Meal IQ score builds upon the dietary recommendations, so it indicates the overall dietary quality. In this study it was only possible to assess the change of the overall Meal IQ score. Further analyses of the development of the single components of the Meal IQ score would be interesting.

In addition to the two studies testing the validity and reliability of the DPM used in the school setting (70,71) two published intervention studies using a DPM in the school setting was identified. In the Wise Mind Project Williamson et al. (105) investigated the efficacy of an environmental approach for prevention of inappropriate weight gain in children. Six hundred seventy school children from the 6th grade took part in the study which lasted two academic years. This multicomponent intervention included changes in the political, personal, social, cultural and physical environment. The DPM was used to measure food selections and plate waste to estimate the food intake for three school meals for each of the participants. The school-based environmental approach for prevention of weight gain in children did not find significant changes in body weight compared to the control group, but the intervention was associated with a reduction of total caloric intake, dietary fat intake, protein intake, and an increased physical activity compared to the control groups. In The Louisiana (LA) Health Study Williamson et al. (106,128) tested the efficacy of two school-based prevention programmes for weight maintenance. Two thousand and sixty children in 4th-6th grades were involved. The LA Health Study used also a multicomponent intervention with more intervention arms. The DPM was used to measure food selection and food intake of the school children on three consecutive days. The duration of the study was 28 months. They reported small effect on weight gain prevention outcomes. A decreased body fat for boys and attenuated fat gain for girls was found and also reduced intake of dietary fat was demonstrated. In both of these studies the DPM was used on 3 consecutive days. To capture the variation of the dietary intake we also measured 3 days in one week. Martin et al. (71) measured children's food intake in a school cafeteria for 5 days and based on analysis of confidence interval widths over the 5 days of measurement it appeared that assessing food intake over 3 days provided a reliable and representative measurement of food intake. Except for the method used for measuring of dietary intake these studies are very heterogeneous from this present study in relation to the actual intervention, age group of the participating children, outcome measures and also the duration of the study. Though in the Wise Mind Project, Williamson et al. (105) explained the improved dietary intake by the significant changes in food selections. This point is very essential, as it suggests that the environmental approach for modifying the preparation and presentation of foods was important in modifying food intake during school meals. This could be compared to the finding of the present study where we also modified/exchanged the food supply and thereby modified the food intake.

The school may play an important role in diminishing some of the socioeconomic differences that are related to health by offering an environment that is available/accessible to all on equal terms. We have collected data on the social class of the families of the children and it could be interesting to look further into the differences of dietary effect of the school food programme according to social class. More analyses on the effect of availability compared to accessibility in children from different social background could be investigated.

5.3.1 Relevance of the measured dietary effect

For the children in the 2nd and 3rd grades the observed increase in Meal IQ score at 1st follow-up was 2.4 and in the 5th and 6th grades the change was 2.3. The range of the Meal IQ score goes from 0-28 and the overall score in the intervention group during the free school meal period was around 13-14. School meals have a better nutrient profile than an average packed lunch though it is not sure that the school meals will provide children with the optimal nutrient intake at lunch time. The present study indicates that there still is room for improvement of the intake at lunch even during the free school meal period. A healthy food supply is important and has in this thesis been found to affect the quality of dietary intake. A higher dietary effect could possibly have been measured if the school children were eating more of the school meals, as data on many leftovers were measured. Future research has to take into account the importance of not just a healthy supply but also focus on the food to be eaten.

The intervention in the present study is an example of an effective population based health promotion initiative where the distribution is moved toward a higher mean value of the dietary quality and thereby toward a more healthy food intake at lunch.

In the analyses we investigated the effect on the mean change of the Meal IQ. It is possible that some of the school children eating the packed lunches with the highest dietary quality are not necessarily having a positive effect of eating school meals instead of the a packed lunch.

The eight schools participating in the evaluation of the school food programme represent different geographical areas in Denmark. Still it is difficult to generalize from such a limited sample. When compared with data from the Danish National Survey of Dietary Habits and Physical Activity (12) the dietary quality of the lunch in Danish school children do not meet the official nutrition recommendations (13) and the dietary guidelines (14). Furthermore most of the Danish children bring a lunch from home (4), thus it is plausible that providing of a free school meal could improve the diet in school children. The limited use of the school food programmes when the lunch is paid by the parents is also described elsewhere (2,3).

5.3.2 Follow-up period and sustainability of effect

The present study was designed with a 2nd follow-up measurement. The circumstances at the follow-up were different from those in the intervention period in the way that the school meals where no longer offered to the school children free of charge. Back in 2007 when the present project was initiated, the Danish Government wanted that school food programmes should be financed at least partly by the parents. From the 2nd follow-up it was possible to investigate the dietary effect of the school food programmes when the school meals were paid by the parents. We found a very limited sustainability and use of the school food programmes. On two of the four schools the school food programme was not sustained and the prevalence of children buying a school meal on the two schools was quite limited. The study showed no dietary effect of the school food programme when the school meals were paid by the parents. An effect might have been found if sub-analyses for the children buying a school meal compared to the ones who had a packed lunch had been conducted unless those who buy school meals are the ones with the most healthy packed lunches. Further analyses could be done to investigate this.

In the present study focus was on the measuring of dietary effect. It would have been interesting to have further investigations on the reason for the limited sustainability and use of the school food programmes and how the financial circumstances affect this. Bere et al. (136) compared in Norway the intake of fruit in 3 groups of 7th grades school children having either free fruit, paid fruit or a no fruit available at the school. They also found that the providing of free healthy food (fruit and vegetables) is an effective strategy to increase school children's intake of healthy food (fruit and vegetables).

Only limited knowledge exists about whether the effect of school-based intervention programmes is sustained beyond the intervention. The studies usually extend about 1-3 years. Only one study investigated the effect of the intervention after 10 year (137,138). It is possible that there is a long term impact of the interventions and thus a long term effect on behaviour could occur.

The duration of the present study was seven months. We found a positive effect of offering free school meals, but we do not know if the effect would sustain if the provision of the free school meals was continued.

It could be hypothesized that the improved quality of the dietary intake from the free school meals could affect the dietary quality of the packed lunches brought from home at the 2nd follow-up measurement. However, the present study showed a decreased quality of dietary intake at lunch at the 2nd follow-up compared to baseline. Focusing on other aspects than the food might have prolonged the effect of the period with the free school meals.

5.3.3 Multicomponent interventions

As illustrated in the ecological framework modified after Story et al.(24) and depicted in Figure 1.1, the present thesis is an example on an intervention where factors in the physical environment are changed namely the availability and accessibility of a school meal. The results suggest that the availability of the school meals are important for a positive dietary effect of a school food programme while at the 2nd follow-up where the school meals are accessible no effect on dietary quality is measured. Williamson et al. (105) concluded in the Wise Mind Study that the primary determinant of the healthier eating among the school children in the intervention group was due to the significant changes in food selection caused by the dietary intervention. Changing the availability/accessibility of food can affect the eating behavior in children, but is no guarantee of a sustained effect. Nutritional education can influence more individual factors (e.g. cognitions and skills) but is unlikely to be effective if the environments do not support this behavior by making healthy food available. Several studies also report a positive effect of including the social environment in the intervention (e.g. the family) (129,139). Operating in a variety of levels and settings is essential for the improvement of dietary intake among school children. This is a central conclusion of ecological models, as it takes the combination of both individual-level and environmental/policy-level interventions to achieve substantial changes in health behaviors (140).

We evaluated the dietary effect of a relatively well-defined intervention targeted the physical environment. Compared to such an intervention it is a challenge to evaluate multicomponent interventions while it is difficult to determine which components contributed to a possible measured effect. A stepwise approach where each of the components is tested separately would be ideal but such approach requires time and money and is often not feasible. It has been suggested that the randomized controlled trial should be questioned as the gold standard for assessing effectiveness of health promotion interventions (141). An alternative system may be needed for evaluating health promotion programmes and process evaluations to explore mediators of effects might be used to a higher extend.

5.4 Strengths and limitations of the main study

The randomized controlled trial with individual random assignment is the gold standard for safeguarding of internal validity (142). In the present evaluation of school food programmes the randomization procedure was not possible because the intervention group was selected among the 38 schools which received funds from the Danish Food Industry Agency to implement a school food programme, which may be considered a limitation. However to improve the study design an experimental control group was selected afterwards among schools without any school food programme and matched with the intervention schools on key variables. No differences were found on these key variables at baseline indicating a food matching.

Danish students eat their lunch during a timetabled lunch break and usually bring a packed lunch from home (4). School meals and the packed lunches have different lunch formats. We measured the dietary quality of the lunch meals eaten in the timetabled lunch break. A limitation of the study could be if pre-lunch consumption of food items from the packed lunch occurred during the morning break, influencing the dietary quality of lunch eaten in the timetabled lunch break where we collected the dietary data on the packed lunches, especially if the children did not eat anything before the lunch break in the period where school meals were served. That could influence both how much and also what was eaten in the timetabled lunch break. Measuring the entire diet would give answer to that question.

The use of the multilevel analysis taking into account the hieratical structure of the data further strengthens the interpretability of the results. If the hierarchical structure of the data (students nested within schools and students within classes) is not utilized in the statistical analyses, this might lead to biased conclusions regarding the effect of school, but this approach is not used in all school-based studies (143,144). We adjusted our analyses for various known or potential confounders, but we cannot exclude confounding through factors that were not considered. We used the difference in Meal IQ score relative to baseline value as outcome measure. The advantage of this approach is the elimination of biological variation. A limitation is that the school children who did not participate at baseline were excluded from the analyses and thus the number of participants was reduced. Yet the rate of children participating was high, at baseline 98.1% participated, at 1st and 2nd follow-up respectively 96.6% and 95.1% participated probably because the collection of data took place at the school and the burden on the school children was low.

The existing Danish school food programmes have been difficult to evaluate because they often have been used by a limited number of children. The allocation of the funds to investigate the school food programme, however increased the use of the school meals and thus offered the possibility to compare the same group of children having either packed lunches, free or paid school meals. The setup of the study gave the unique opportunity to evaluate a project which could contribute to credible evidence to the school food arena.

The combination of the DPM and Meal IQ is an advantage, as it is a cost-effective approach for measuring and assessment of the quality of dietary intake among school children aged 7-13 years.

5.5 Implications for future research in the school food arena

The hypothesis that the school should contribute to the protection of children's health by promoting healthy diets is supported among many experts (21-25,145). The results of the thesis suggest national implications for school food programmes where school meals are offered for free. This strategy may improve the dietary quality of lunch consumed. Several countries have found that low funding was a major barrier for implementing healthy nutrition in schools (23). If the school meals are not offered for free it will require additional research on how school food programmes can be better implemented, including knowledge about the economic perspective of this area.

School food programmes are nutritionally important and could also become part of the political agenda. The present study confirms that if the school meals are to be paid by the parents the use and sustainability may be limited, and if the area is not a priority politically other strategies may be considered. A total of 85 % of Danish school children aged 7-14 years eat a packed lunch from home (4). The packed lunches could be nutritionally improved. Lunch is a very cultural concept and it would be interesting to investigate the possibility of improving the dietary quality of the packed lunches brought from home. E.g. activities and policies to encourage parents and children to improve the dietary quality of the packed lunches by including more nutritious foods such as fruit, vegetables and low fat starchy foods. Such an intervention could still exploit the advantages of the school setting. Cooper and Jones (146) introduced a healthy eating initiative in schools and showed a significant improvement in the quality of packed lunch food while less fatty and sugar items and more fruit and vegetables were eaten. Evans et al. (147) evaluated a "SMART lunch box" intervention with the aim to improve the food and nutrient content of children's packed lunches. Children in the interventions group were provided with more fruit, vegetables, dairy and starch food and less savoury snacks compared to the control group. The changes were small and Evans et al. conclude that further interventions are required to bring packed lunches in line with the government standards for school meals in UK. The same still has to be shown in a Danish setting.

This PhD thesis presents one of the four work packages in the interdisciplinary project EVIUS (EffektVurdering af Interventioner omkring frokost for børn og Unge I Skoler) focusing on the dietary evaluation of the school food programme and the other work packages focused on other aspects. It is possible that further cooperation between the work packages would have given the opportunity to create even more credible knowledge about the school food arena as a setting for health promotion. That would have given the possibility to do an interdisciplinary evaluation on the same schools and on the same individuals/target groups at the schools. Though it had been ideal it was not possible in the present setting. The results of the different sub-projects could be critically reviewed and used to design a multicomponent school-based intervention study. The discussion should focus on how such an intervention should be designed and evaluated. De Bourdeaudhuij et al. (30) suggest that time has come to move to the implementation of sustainable interventions under real life conditions while more research is needed on which interventions can also be implemented in the schools without a continued need for external help or support from a research team.

Children stay in the school for many hours every day and consume 30-50% of their daily energy intake at school (148). Thus, the dietary quality of the food eaten may have a significant impact on their overall diet quality. In future research it is important not just to measure the food eaten in the timetabled lunch break but throughout the whole school day or ideally the whole day. It is uncertain if the overall dietary quality of the diet for the whole day is influenced by the dietary quality of the lunch or if a poor or healthy dietary intake is compensated for the rest of the day. In a cross-sectional study Rogers et al. (49) compared quality of dietary intake from packed lunches and school meals. The diet was assessed by a 3-day non-weighed food record among 621 school children aged 7 years. The quality of dietary intake from the school meals was better than that from the packed lunches and Rogers et al. found that the differences according to type of meal persisted when the nutrient intake of the whole day was assessed (49). Another cross-sectional study confirmed that the lunch eaten at school reflect the overall eating patterns among 531 school children aged 11-16 years (149). In another cross-sectional study Gatenby (40) also found that school meals compared to packed lunches resulted in consumption of a healthier lunch among 147 school children aged 8-11 year. Gatenby suggested that the differences in intake were compensated for by other food consumed during the day, such that daily nutrient intakes were not significantly different. The dietary intake of the entire day was assessed in a subsample of 20 children, 10 receiving school meals and 10 packed lunches. A five-day food diary was used for this purpose, and thus the strength of this finding is limited and has to be investigated further.

6. Conclusion

This PhD thesis presents the evaluation of a school food programme where the dietary effect of providing free and paid school meals compared to packed lunches brought from home was investigated. For this purpose relevant methods were developed and validated.

The conclusions of the thesis are:

The standardized DPM is an appropriate method for collection of data on dietary intake from a pediatric population, because the DPM overcomes the recall problems and difficulties in portion size estimation. Furthermore the DPM enables data collection for a large population. The DPM was demonstrated to be valid and reliable for assessing the dietary quality of packed lunches brought from home for children aged 7-13 years.

The developed Meal IQ is an easily applied evaluation tool for assessing the dietary quality of packed lunches brought from home and school meals. The Meal IQ was found to be valid, simple, flexible with regard to the different types of lunch meals and sensitive enough to measure relevant differences when children eat school meals instead of packed lunches brought from home.

The DPM in combination with the Meal IQ was found to be useful and cost-effective for evaluation of health promotion interventions in schools.

The intervention study demonstrated that implementing a school food programme increased the quality of dietary intake among school children aged 7-13 years in the period where the school meals were provided for free compared to packed lunches brought from home. When the parents paid the cost of the school meals very few school children did buy a school meal and there was no difference in quality of dietary intake among children in the intervention and control schools. The dietary effect of the school food programme did not depend on age. The school children in the 5th and 6th grades had generally a lower dietary quality of intake from the lunch, which could be explained by more skipped meals in this age group compared to children in the 2nd and 3rd grades.

7. Perspectives

School-based healthy eating provides a great opportunity to enhance the future health and well-being of children because they can reach almost all children and may enhance learning and health during critical periods of growth and maturation and help to establish healthy dietary behaviors at an early age that will lead to lifelong healthy dietary habits.

In the future we must refine the methods for dietary assessment to be able to accurately assess the dietary intake of school children so that we can monitor dietary intake trends, make accurate research and implications for policy decisions.

Future studies have to examine the possibility of using the DPM to estimate food intake in free-living conditions among children. This aspect would be important if the entire diet has to be measured. Alternative research could be done on whether the dietary intake observed during one or more meals is predictive of 24-hour dietary intake.

In the future we have to utilise the technology more when we collect and assess dietary data. Automation of the dietary evaluation including the portion size estimation would decrease the burden on the researcher and thereby improve the cost-effectiveness and possibly the accuracy of the method.

In the evaluation of the school food programme we analysed the dietary quality of the food intake. It could be interesting to look more into the dietary quality of the leftovers and the importance of these for the dietary quality of the lunch consumed.

Recording bias may occur when data on diet is collected. The DPM is unobtrusive and would probably not influence the usual eating patterns of the children but this is still unclear and need to be investigated further.

Overall the school has the potential to play a substantial role in health promoting activities related to healthy eating. This evaluation shows that there still is a way to go. Based on the knowledge of all the environments and factors which affect children’s dietary behaviour future research has to focus on development of sustainable multicomponent school-based interventions which can be implemented in the schools without a continued need for external help or support. The focus of such an intervention could be implementing of a school food programme. Another focus could be improvement of the packed lunches brought from home with the purpose to contribute to the shaping of healthier dietary behaviour among Danish school children.

A coordination of sharing of knowledge on e.g. which components are important for the effectiveness of a school food program could improve future work in the school setting in Denmark as well as in a more global perspective.

Thus it is my hope that this PhD thesis may contribute with inspiration, relevant tools and methods for measuring and assessing dietary intake in health promotion interventions and thereby provide credible evidence regarding healthy eating in the schools and other settings.

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Papers

Paper I

Validation of a digital photographic method for assessment of dietary quality of school lunch sandwiches brought from home

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Original Article

Validation of a digital photographic method for assessment of dietary quality of school lunch sandwiches brought from home

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Abstract

Background: It is a challenge to assess children's dietary intake. The digital photographic method (DPM) may be an objective method that can overcome some of these challenges.
Objective: The aim of this study was to evaluate the validity and reliability of a DPM to assess the quality of dietary intake from school lunch sandwiches brought from home among children aged 7–13 years.
Design: School lunch sandwiches ($n = 191$) were prepared to represent randomly selected school lunch sandwiches from a large database. All components were weighed to provide an objective measure of the composition. The lunches were photographed using a standardised DPM. From the digital images, the dietary components were estimated by a trained image analyst using weights or household measures and the dietary quality was assessed using a validated Meal Index of Dietary Quality (Meal IQ). The dietary components and the Meal IQ obtained from the digital images were validated against the objective weighed foods of the school lunch sandwiches. To determine interrater reliability, the digital images were evaluated by a second image analyst.
Results: Correlation coefficients between the DPM and the weighed foods ranged from 0.89 to 0.97. The proportion of meals classified in the same or an adjacent quartile ranged from 98% (starch) to 100% (fruits, vegetables, fish, whole grain, and Meal IQ). There was no statistical difference between fish, fat, starch, whole grains, and Meal IQ using the two methods. Differences were found for fruits and vegetables; Bland–Altman analyses showed a tendency to underestimate high amounts of these variables using the DPM. For interrater reliability, kappa statistics ranged from 0.59 to 0.82 across the dietary components and Meal IQ.
Conclusions: The standardised DPM is a valid and reliable method for assessing the dietary quality of school lunch sandwiches brought from home.

Keywords: *food intake*; *packed lunches*; *diet assessment*; *children*

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Childhood represents an important life stage for the development of healthy nutritional behaviour, and some evidence exists that nutritional behaviour tracks from childhood into adulthood (1). The dietary habits of children in Denmark (2), as well as for children in other Western countries, call for improvement (3). Assessment of children's dietary intake may be complicated, and inaccurate reporting from both children and parents in dietary surveys has been recognised as a challenge (4). Weighed food records, food diaries, food frequency questionnaires, diet histories, and 24-h dietary recalls are all common methods for estimating dietary intake; however, these methods rely on self-reporting with a relatively high respondent burden.

The accuracy of self-reported methods has been questioned. Studies using doubly labelled water have shown that misreporting of food intake is a common problem for these methods (5–7). Especially when collecting data on dietary intake in a paediatric population, self-reported methods become a challenge. Before the age of 12, children have not yet developed the cognitive skills required by the self-reported methods (4). One of the particular challenges among children is quantification of the dietary intake, and it is difficult for children to estimate portion sizes (4, 8). Thus, there is a need for valid alternative methods to capture actual dietary intake – for example, to evaluate intervention studies aiming to improve the diets of different population groups, especially children. Collecting and analysing dietary intake data from large samples can be time consuming and expensive, but this is important when designing powerful studies. Recently introduced methods applying new technologies have been used that may improve the quality and accuracy of dietary assessment methods (9). These methods may also prove useful for collecting data from a large population.

The digital photographic method (DPM) is a relatively new method. It overcomes children's recall problems and difficulties in estimating portion sizes, and it also minimises the burden of the respondent. The method is unobtrusive, highly reliable, and highly valid when used to estimate the food intake of individual meals of adults and school children in cafeteria settings (10–13). The DPM is also appropriate for collecting data from a larger population group.

It is relatively easy to get information on the composition of lunches provided by the schools, because recipes are available and through them more information on the non-visual food items; furthermore, the meals are often standardised. However, it can be a major challenge to collect objective data on lunches brought from home. In Denmark, school lunches brought from home usually comprise open sandwiches (often on rye bread) with spread and cold sliced meat, sometimes with fruits and vegetables (14). To our knowledge, the method has not yet been tested on this type of meal.

The aim of this study was to evaluate the validity and reliability of a DPM to assess the quality of dietary intake from school lunch sandwiches brought from home among children aged 7–13 years.

Methods

Study sample

A total of 191 school lunch sandwiches were prepared based on digital images from a database comprising 2735 school lunch sandwiches brought from home. The database was developed as part of another project where school lunch sandwiches were collected from 8 schools representing different geographical areas in Denmark and from children aged 7–13 years. The size of the study sample was chosen to ensure presence of all relevant food components examined in the dietary assessment procedure (especially fish and snack products) described below. Around 200 lunches would ensure this aspect and because there were 8 schools and two age groups, 12 lunches from each age group and from each of the 8 schools were randomly selected – in total 192 lunches. One meal was excluded because it consisted of only beverages. When the digital images were collected for the database all children were asked to show clearly any non-visible food items (like spreads). During the preparation of the school lunch sandwiches the weight in grams of each food component was registered using a Soehnle 8026 digital balance (0–1,000 g = 1 g, 1,000–2,000 g = 2 g). A digital image was taken of the final lunch following the procedure described below.

DPM procedure

A standardised DPM was developed to collect data on the school lunch sandwiches. The meals were photographed using a digital camera (Nikon S700) mounted on a tripod with the lens 0.37 m above the meal with a camera angle of approximately 45° – a procedure that allows visibility of the foods in three dimensions in a digital image. To standardise the digital images, a placemat (0.6 × 0.6 m) with markings for placement of the plate and some standardised cutlery were fixed to a table. The placemat was divided into squares of 2 × 2 cm to support the estimation of the size and weight of the different food items. Markings were also made for where to place the camera tripod. To optimise and standardise the quality of the digital images, a cube light was used (Fig. 1). The research staff attended a training session on the use of the DPM before the data were collected.

Validation of the DPM

The Meal Index of dietary quality

A Meal IQ that was developed as a scoring system and published earlier (15) was applied as the tool to assess the dietary quality from the digital images and from the weighed school lunch sandwiches (Fig. 2). The Meal IQ consists of the following seven components based on dietary issues related to children aged 7–13 years and the visibility of the components: total fat, saturated fat, whole grain, snack products, fish, fruits, and vegetables. From these components, a total Meal IQ score is obtained.

Fruits, vegetables, and fish were estimated in grams. To estimate total fat, saturated fat, whole grain, and snack products in the lunch meals, unit sizes were defined in terms of household measures, such as slices, cups, and pieces (16). The total Meal IQ score for a single meal can range from 0 to 28 [for more details on the Meal IQ, see Ref. (15)].

Assessment of dietary quality

The components of the Meal IQ and the total Meal IQ score were determined from the objectively weighed 191 school lunch sandwiches. Fruits, vegetables, and fish were

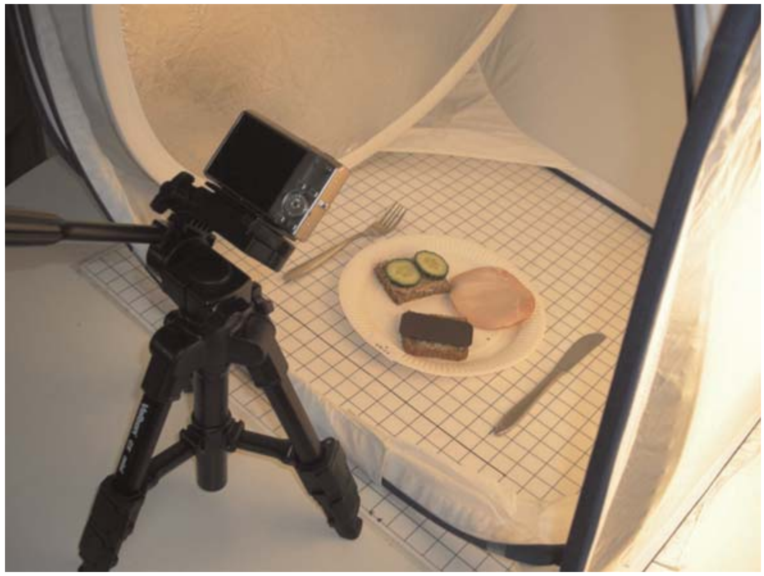

Fig. 1. The standardised digital photographic method.

already registered in grams, and although weights in grams were assigned to each of the units, it was possible from the registered weights of the food items to calculate the number of fat, saturated fat, starchy, and whole-grain units (to measure the relative (total) fat content of the meal, the number of fat units was subtracted from the number of starchy food units).

The components of the Meal IQ and the total Meal IQ score were also determined from the digital images. To support the conversion of food items in the digital images into weights and unit sizes, reference material was developed. The reference foods were selected to represent the foods most frequently consumed at school lunch by children who brought lunches from home, selected on the basis of the 191 meals representing the study sample. Each food item was photographed in up to eight different portion sizes, and prepared or cut in different ways. The food items were also photographed in different positions on the plate – at the back and the front and at one of the sides of the plate. The reference foods were photographed with exactly the same camera angle and distance from the food, using a cube light so that the apparent size of all foods remained constant across the digital images. These reference foods were supplemented with material from a previous study also using a standardised DPM (17), which were also relevant for the estimation of school lunches. The total collection of photographed reference foods consisted of seven different fruits; 16 vegetables;

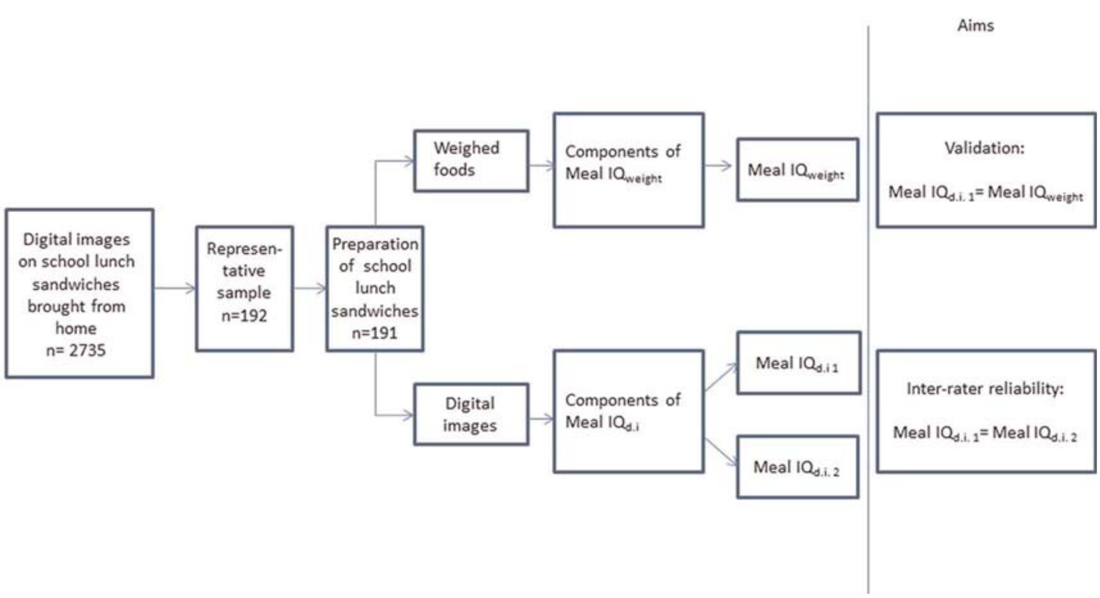

Fig. 2. Study design. d.i.: digital images.

six fish; nine starchy foods such as bread, rice, pasta, and potatoes; and 22 fatty foods such as butter or spread, meat, and dressing.

Some food items are in standardised portions. These products were not photographed but instead presented in reference lists. Some fatty foods (e.g. sliced meat) were presented in a reference list containing information about typical portion sizes and information on content of fat per 100 g and per portion of the food item, which is necessary for estimating the fat units [see Ref. (15)]. Different fish products were also presented in a reference list with information on the content of fish in a mixed product (e.g. tuna in tuna fish salad spread). Information on starchy food products was also put in a reference list, and in addition to the information on the weight of standard portions, information was also given regarding whether the product was categorised as whole grain. Finally, a reference list of snack products and their content of fat and starch per standard portion was available.

If food items that did not make their fat content visible were presented in the digital images, for example, we used data from GfK (Gesellschaft für Konsumforschung) Denmark, which does market research, to determine the type of product. The assessment was in these cases based on information on the most used product of the category (18). If the digital images showed composite dishes or products for which no declaration was available, for example because the dishes or products were homemade, data from the Danish National Survey of Dietary Habits and Physical Activity (2) were used to assess the dietary composition.

A database was developed using Microsoft Excel for the dietary assessment of the 191 digital images in order to make the necessary notes on the dietary components (grams or units) while watching the digital image.

Ten school lunch sandwiches were used to train the image analysts in portion size estimation on the basis of the photographed reference foods and reference lists. Different persons handled the test and reference methods.

The standardised DPM was validated, testing the agreement of the dietary components included in the Meal IQ and the overall Meal IQ score obtained using the digital images and the weighed foods of the lunches (Fig. 2).

Reliability testing of the DPM

Interrater reliability testing was conducted on the standardised DPM to assess the ability of the method to yield consistent results for the amount of fruits, vegetables, fish, and fat units (inclusive saturated fat units); the amount of starchy units (inclusive units from whole-grain products); the presence of snack products; as well as the overall dietary quality measured by the Meal IQ score by two raters. The two digital-image analysts' ratings were compared for each dietary component and the total Meal IQ score for the 191 digital images of the school lunches.

Statistical analysis

Most of the dietary data were non-normally distributed, both before and after log transformation; therefore, medians and 5th and 95th percentiles are presented. The Wilcoxon signed-rank test was used to analyse the difference in dietary components, and the Meal IQ assessed by the DPM and the food record method.

To validate the DPM, correlation coefficients between the selected dietary components and the Meal IQ estimated from the digital images and from the weighed foods were assessed. As the data on dietary intake were not normally distributed, Spearman's correlation coefficient was used (19). The estimated components and the total score of Meal IQ in quartiles were classified. Gross misclassification was defined as classification in the opposite quartile when observed in the highest or lowest quartile. To evaluate the agreement between the continuous variables (fruits, vegetables, and fish) and the Meal IQ score assessed from the digital images and the weighed foods, Bland–Altman plots were made. The limits of agreement were defined as two times the corrected standard deviations of the differences above and below the mean (20).

To test the interrater reliability of the DPM, a weighted kappa statistic was calculated for each of the dietary components and the Meal IQ. To conduct the kappa statistics on the continuous components and the Meal IQ, the variables were divided into 10 groups according to percentiles.

In the analysis specific for fruits, vegetables, and fish, the meals not containing the respective food item were excluded from the analysis in both the validity and reliability testing.

$P < 0.05$ was considered statistically significant. All reported P values were based on two-sided hypotheses. Statistical analyses were carried out using the SAS statistical software package (version 9.2, SAS Institute Inc., Cary, NC, USA).

Results

Validation of the DPM

Each of the dietary components and the Meal IQ were estimated from the digital images and the weighed foods of the lunches. Table 1 shows the values of the medians and the 5th and 95th percentiles of the dietary components and the total score of the Meal IQ assessed from the two methods. The Wilcoxon signed-rank test showed that no statistical difference was found between fish, fat, starchy, and whole-grain units and the Meal IQ score assessed from the digital images and the weighed foods.

Table 1. Dietary components and the Meal IQ score estimated from weighed foods and digital images (median and 5th and 95th percentiles)

Components	*n*	Actual content from weighed foods: median (P5, P95)§	Estimated content from digital images: median (P5, P95)§	*P* values for differences	Classified into same/same or adjacent quartile (%)	Correlation coefficients Spearman$
Fruits (g)	67	87 (13; 195)	80 (15; 174)	<0.0001	84/100	0.96
Vegetables (g)	130	52 (10; 141)	48 (10; 125)	0.0003	76/100	0.96
Fish (g)	21	24 (11; 50)	22 (7; 52)	0.0611	81/100	0.89
Fat units	191	1.5 (0; 4.5)	1.5 (0; 5)	0.0855	79/99	0.93
Saturated fat units	191	1.5 (0; 4)	1.5 (0; 4)	0.0457	72/99	0.91
Starchy units	191	1.75 (0.5; 3.5)	1.75 (0.5; 3)	0.2344	74/98	0.89
Whole grain units	191	1 (0; 2.5)	1 (0; 2)	0.0615	87/100	0.96
Meal IQ score	191	16 (5; 20)	16 (6; 20)	0.3394	80/100	0.97

§P5: 5th percentile; P95: 95th percentile.
$All Spearman's correlation coefficients were significant, $P<0.001$.
P values for Wilcoxon signed-rank test and cross-classification and correlation analysis between values estimated by the digital and the weighed foods

The *P* value for the difference between the saturated fat units was also significant ($P=0.0457$). Fruits and vegetables were significantly different when assessed from either the digital images or the weighed foods (Table 1).

The Spearman correlation coefficients between the dietary components and the Meal IQ estimated from the digital images or the weighed foods were highest for the Meal IQ score ($r=0.97$) and lowest for fish and starchy units ($r=0.89$) (Table 1).

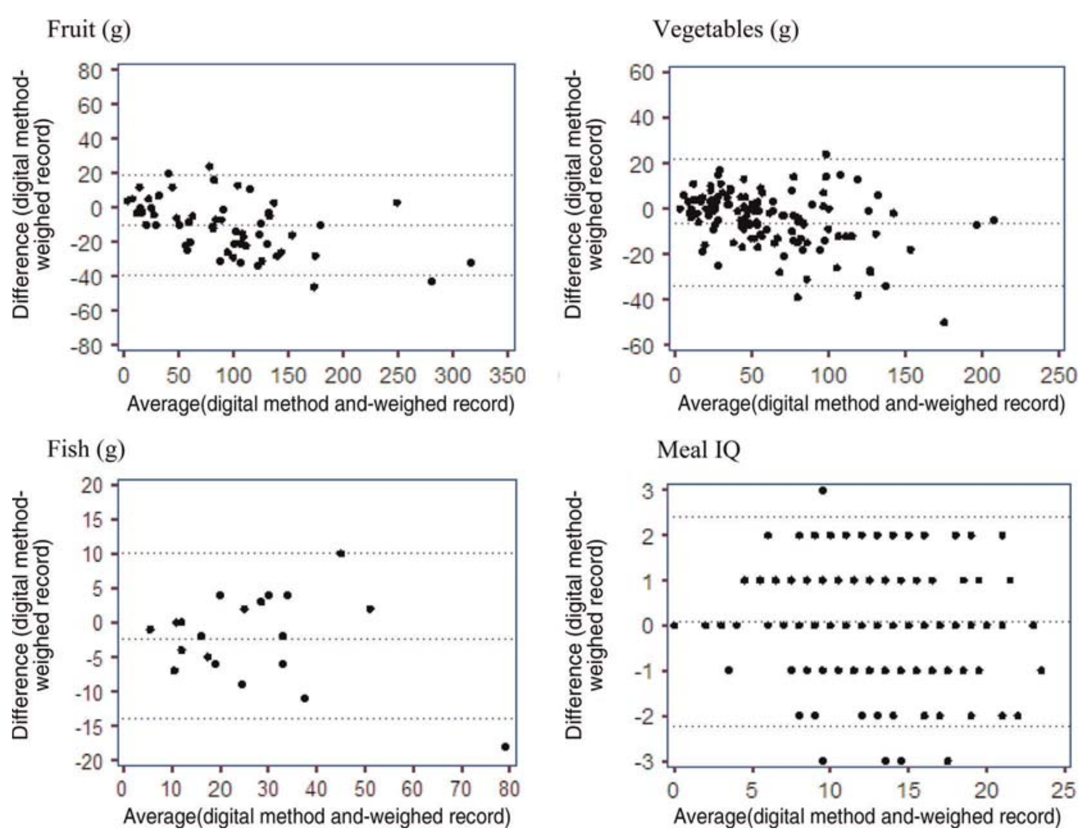

Fig. 3. Bland–Altman plots of agreement on the weight of fruits ($n=67$), vegetables ($n=130$), and fish ($n=21$), and the score of the Meal IQ ($n=191$) obtained from the digital photographic method vs. the weighed foods. The *x*-axis shows the mean of the two methods, and the *y*-axis shows the difference between the digital photographic method and the weighed foods. The middle line denotes the mean difference (bias), whereas the top and bottom lines show the upper and lower limits of agreement.

Table 2. Interrater reliability measures of the digital photographic method using weighted kappa test statistics ($n = 191$)

	Interrater	Reliability
Components in Meal IQ	Kappa	95% confidence interval
Fruits	0.82	0.76–0.88
Vegetables	0.79	0.75–0.83
Fish	0.70	0.60–0.79
Fat units	0.69	0.63–0.74
Saturated fat units	0.69	0.64–0.75
Starchy units	0.59	0.52–0.66
Whole-grain units	0.76	0.68–0.84
Presence of snack products	0.80*	0.69–0.91
Meal IQ	0.76	0.72–0.81

*Simple kappa coefficient.

The proportion of meals classified in the same or adjacent quartiles of dietary intake ranged from 98% (starchy units) to 100% (fruits, vegetables, fish, and whole-grain units, and total score of Meal IQ). Gross misclassification was not found for any of the dietary components or the total Meal IQ score (Table 1).

Snack products were present in only 13 of the 191 lunches, and the assessment of the occurrence was correct in all the cases.

Figure 3 shows the Bland–Altman plots for the continuous dietary variables (fruits, vegetables, and fish) and the Meal IQ score. The amount of fruits estimated from the DPM was compared with the true weight from the weighed food record. The bias was -4.27 g, with the 95% limits of agreement between -29.4 and 20.8 g. Estimation of the amount of vegetables from the DPM had a bias of -6.19 g compared with the weighed food record, and 95% limits of agreement of -34.5 and 22.2 g. When compared with the true amount of fish, the DPM showed a bias of -2.33 g and 95% limits of agreement from -14.7 to 10.0 g. The mean of the difference of the Meal IQ score between the methods was 0.07, and the 95% limits of agreement were ± 2.33 around the bias.

Reliability testing of the DPM

The results for interrater reliability of the dietary components and the Meal IQ are reported in Table 2. Interrater reliability of the estimated dietary components from the DPM showed kappa coefficients that ranged from 0.59 to 0.82 across all components. The variable that yielded the lowest kappa statistic was starchy units. The most reliable variable was the amount of fruits. The Meal IQ yielded a kappa coefficient of 0.76.

Discussion

This study is the first to investigate if a standardised DPM is valid and reliable for assessment of selected dietary components and the overall dietary quality of school lunch sandwiches brought from home.

The analysis of the difference between the amount of fruits and vegetables estimated from the digital images shows a difference from the weighed foods, despite almost the same medians and averages of these variables. The Bland–Altman analyses show acceptable limits of agreement for fruits (-29.4 and 20.8 g) and vegetables (-34.5 and 22.2 g), with some variability but on the same level as found by others (17). The smaller sample of the analyses for fruits ($n = 67$) and vegetables ($n = 130$) affects the variability and the limits of agreement. The Bland–Altman plots illustrate a tendency of increasing underestimation with increasing intake when using the DPM; however, both correlation coefficients were high ($r = 0.96$ for both variables), and the cross-classifications illustrate that the ranking of the individual meals was good for both fruits and vegetables (100% was classified in the same or adjacent quartile).

When estimating the defined units of fat, starch, and whole grains from the digital images, no statistical difference from the weighed foods was shown. It is easier to estimate variables in household measures, because they do not require the same degree of accuracy as the variables assessed in grams. But for fish, no difference between the estimated amount from the digital images and the true weight from the food record was found, probably because it is easier to estimate the relatively small amounts of fish compared to the voluminous and especially large quantities of fruits and/or vegetables. The Bland–Altman analysis for fish shows tight limits of agreement (-14.7 to 10.0 g), but also for this food item, the Bland–Altman plots illustrate a tendency towards larger variability of the range of intake. This result must be treated with caution, since the sample for the fish analyses is relatively small ($n = 21$). We found a difference in the saturated fat units between the methods, probably because of wrong assessment of the spread used on the bread, since it can be difficult to assess whether it is butter or, for example, margarine.

The Meal IQ consists of both the variables estimated in grams and components assessed in units. Compared to the results from the weighed food record method, the DPM was found to provide a good assessment of the overall dietary quality assessed by the Meal IQ. No difference was found between the Meal IQ score assessed using the two methods ($P = 0.3394$). The Bland–Altman plot shows a small bias (0.07), and the limits of agreement are sufficiently tight to suggest good agreement between the methods (-2.26 to 2.40). The Meal IQ is not influenced by the underestimation of fruits and vegetables with increasing intake. Fruits and vegetables are separate components in the Meal IQ, and each component in the Meal IQ scores from 0 to 4 points. If fruits or vegetables are not represented in the meal, the score is 0; and if

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the meal contains 75 g or more, 4 points are given (15). Further analyses show that the problem of underestimating fruits and vegetables does not exist when estimating weights under 85 g of vegetables and 115 g of fruits.

The correlation coefficients between the dietary components and the Meal IQ assessed from either the DPM or the weighed food record were high ($r = 0.89$–0.97). Correlation analyses are often used to validate dietary assessment methods, but correlation coefficients provide only a limited measure of the level of agreement between two methods and should therefore not be used alone. Correlation coefficients depend, for example, on the range of the true quantity in the sample (20). In this study, the correlation coefficients were supplemented with cross-classification of the individual meals. This was also good for the dietary components as well as the Meal IQ. In addition, the Bland–Altman plots used for assessment showed acceptable limits of agreement.

In this study, the interrater reliability was assessed from kappa statistics. The kappa coefficient shows a moderate strength of agreement for the assessment of starchy units by the two raters ($\kappa = 0.59$), very good agreement in estimating the amount of fruits ($\kappa = 0.82$), and good agreement for the other components ($\kappa = 0.69$–0.80) and the Meal IQ ($\kappa = 0.76$) (21). Other studies have evaluated the interrater reliability by calculating intraclass correlation, and they also found a good interrater reliability, with intraclass correlations on the level of 0.80–0.96 for different parameters when using the DPM (12, 13, 17).

The validity and reliability of the method are highly dependent on the skills of the image analysts. To reduce the variability caused by using many raters, intensive training of one or possibly two raters might be preferable to training many raters. Also, future training procedures of image analysts should focus on the underestimation we found, especially for the high amount for fruits and vegetables. Others have also reported underestimation when using the DPM (17, 22, 23).

An advantage of the DPM is the opportunity to collect dietary intake data from large populations (9) (e.g. in intervention studies where dietary data have to be collected and where data on meals should be evaluated). Another advantage is that the burden on the participants is minimal compared to that of other dietary assessment methods, and the method also overcomes the recall problems of children. The visual estimation technique is the most comparable method to the DPM. This method is also shown to be valid and reliable (12) and would overcome some of the same challenges as the DPM. But the advantages of using the DPM instead of the visual estimation technique are rapid collection of the dietary data in the eating environment, convenience for participants and researchers, and the possibility of uninterrupted evaluations of the foods that are studied on the digital images, as opposed to evaluation in the setting for data collection (12).

The most time-consuming step when using the DPM for dietary assessment is the nutritional evaluation, due to reliance on human analysts to estimate food intake and possibly subsequent calculations of the nutrient content. To make the method as cost-effective as possible, we used the Meal IQ in addition to the individual dietary components to assess the dietary quality of the lunches. The Meal IQ score is obtained easily through a simple evaluation process. There is no need to calculate the nutrient content, which would make the calculation of the total score more complex and labour intensive.

It is challenging to assess digital images of school lunch sandwiches brought from home rather than school lunches provided by the school, because recipes and product specifications are not available. But we believe that the method is appropriate for this type of meal as well, because the school lunch sandwiches brought from home normally consist of bread, spread, sliced cold meat, and a piece of fruits or some vegetables, often in relatively standardised portions. A limitation of the DPM may be the dependence of visibility of the food or nutrient of concern. The digital images do not always show details about particular foods (e.g. fat-reduced products). In this study, we used data from GfK Denmark to determine the type of product when the digital image gave too little information (18). In addition, data from the Danish National Survey of Dietary Habits and Physical Activity were used to obtain information on the dietary composition of composite dishes or products. Composite dishes or products are not a big challenge in lunches brought from home for children aged 7–13 years, because they do not often occur. Others have also reported the challenge connected with estimating mixed dishes when assessing dietary intake (12).

The DPM is very unobtrusive and would probably not influence the usual eating patterns of the children, but this is still unclear.

This study shows that the DPM in combination with the Meal IQ is valid and reliable when used to assess the quality of dietary intake from school lunch sandwiches brought from home. There is no reason to believe that the DPM in combination with the Meal IQ would be less accurate with adults. The Meal IQ has to be adjusted just a little, so the cut-off points for the different components included in the Meal IQ are adapted to the official recommendations for adults.

Compared to the more traditional dietary assessment methods, the DPM has mainly been used to collect data on individual meals. Measuring the entire diet of free-living individuals complicates the usability of the DPM. Normally, the respondents are not involved in the collection of data. If the whole diet has to be assessed, it will require that the respondents capture the digital images themselves, thereby introducing greater burden on the respondent and the possibility of increased estimation errors because of lower photo quality and a decreased standardisation of the method. The higher response burden could also affect the compliance negatively. Some studies have examined the possibility of assessing food intake among free-living people. Lassen et al. (17) used a DPM in private homes where the participants were instructed on how to capture digital images on their evening meals to standardise the procedure. Lassen et al. concluded that the DPM for this purpose was valid and feasible. Martin et al. (24) developed a remote food photography method that builds on the DPM. Smartphones were used to capture images of food selection and plate waste and to send the images to a server for food intake estimation. This method was developed specifically to measure energy intake in free-living adults and has proved to be valid.

When food selection and also food intake have to be measured, the standardised DPM is most appropriate when the study population eats in a cafeteria or a classroom, because this makes it possible to collect data on the leftovers. In Denmark, the oldest students often go outside the school during the lunch break, which complicates the use of a standardised DPM. Other methods that incorporate technology would be appropriate for this target group. Boushey et al. (25) found a strong preference for technology methods among adolescents, compared to pen-and-paper records. Maybe using a smartphone as described by Martin et al. (22, 24) would be appropriate to take into account the eating behaviour of young people, or a personal digital assistant with a camera and mobile phone card, as described by Wang et al. (26).

There is much potential in technological methods for assessment of dietary intake, and future advancements are possible (27, 28). Future studies have to examine the possibility of using the DPM to estimate food intake in free-living conditions among children; this aspect would be essential for the possibility to measure the entire diet. Furthermore, research on whether the dietary intake observed during one or more meals is predictive of 24-h dietary intake could also be done.

Automation of the nutrient evaluation could be developed and would improve the cost-effectiveness of the method.

In conclusion, the standardised DPM is a valid and reliable approach for assessing the dietary quality of school lunch sandwiches brought from home for children aged 7–13 years. The method does not rely on the respondents to estimate portion sizes and overcomes the recall problems that exist when collecting dietary data on children. The method is cost-effective and enables data collection for large numbers of people. The method is potentially useful for evaluating the effect of different intervention programmes on dietary behaviours from diverse population groups across different ages.

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Conflict of interest and funding

The authors declare no conflict of interest.

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Paper II

Development and validation of a Meal Index of dietary Quality (Meal IQ) to assess the dietary quality of school lunches

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Development and validation of a Meal Index of dietary Quality (Meal IQ) to assess the dietary quality of school lunches

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Abstract

Objective: School lunch programmes are one strategy to promote healthier dietary habits in children, but better evaluation tools for assessing the dietary quality of such programmes are needed. The aim of the present study was to develop and validate a simple index to assess the dietary quality of school lunches for children aged 7–13 years.
Design: A Meal Index of dietary Quality (Meal IQ) was developed to consist of seven components (nutrients and food groups) based on dietary issues for children aged 7–13 years, which were identified in a national dietary survey. The Meal IQ was validated against calculated nutrient contents of school lunches both provided by the school and brought from home.
Setting: At eight public schools from all over Denmark, data were collected on 191 individual lunches brought from home (which is most common in Denmark) and thirty-one lunches provided as part of a school food programme. In addition thirty-two lunches provided at eighteen other public schools were included.
Subjects: A total of 254 school lunches.
Results: A higher Meal IQ score was associated with a higher overall dietary quality, including lower contents of fat, saturated fat and added sugars, higher contents of fibre, various vitamins and minerals, and more fruits, vegetables and fish.
Conclusions: The Meal IQ is a valid and useful evaluation tool for assessing the dietary quality of lunches provided by schools or brought to school from home.

Keywords
Diet assessment
School meals
Packed lunches
Score

The school has been recognized as an important setting for health promotion, especially eating habits among children[1]. In Denmark, it has been common practice for most children to bring their lunch to school from home, but more recently several initiatives with school food programmes have been introduced, one of the main objectives being to improve the dietary habits of school-aged children.

To investigate if school food programmes actually improve children's dietary intake at school, it is important to have appropriate tools for evaluating such health promotion initiatives. However, one of the challenges with regard to diet is the lack of simple and valid dietary assessment tools to monitor possible differences in the dietary quality between lunches provided as part of a school food programme and lunches brought from home.

Dietary quality indices have received increased attention and may be used as a simple and quick assessment of overall diet quality in order to evaluate adherence to dietary guidelines or guidelines for the prevention of a specific disease, as well as to monitor dietary changes[2].

A variety of dietary indices have been developed to assess overall dietary quality based on different assessment methods and data for a varying number of days. The dietary indices have mainly been proposed for adults[3–10], but indices specifically for children have also been developed. The Preschoolers Diet–Lifestyle Index (PDL-index)[11] and the Revised Children's Diet Quality Index (RC-DQI)[12] focus on pre-school children. The Youth Healthy Eating Index (YHEI) has been developed and used for children and adolescents[13].

Most indices assess the dietary quality of the total diet, whereas indices reflecting the nutrient quality of single meals, including school lunches, remain limited. A Simple Healthy Meal Index (SHMI) was developed to reflect the nutrient profile of single meals provided by canteens for adults[14]. Kremer *et al.* developed a school food checklist, with food and beverage categories, which was designed to estimate children's average energy intake from foods and beverages available in a school setting[15]. There, the focus was on the quantity, measured in the energy content of the meal, and not on the quality.

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However, there is a need for a tool for scientific purposes where the focus is on the dietary quality of a single meal for school-aged children. The requirements for such a tool are that it has to be simple; it must be flexible with regard to the different types of meals; and it must also be sensitive enough to measure relevant differences when children eat lunches provided by the school instead of lunches brought from home.

The aim of the present study was to develop and validate an index for assessment of dietary quality of school lunches, either brought from home or provided by the school.

Experimental methods

Study sample

Data for the validity study came from a school food programme intervention study in which eight schools from all over Denmark participated. A standardized digital photographic method[16] was used to collect data on the lunches brought from home by students in the second and third grades (7–10 years) and fifth and sixth grades (10–13 years). The digital images were used to assess typical lunches among schoolchildren in Denmark in the present study. A sample of 191 lunches brought from home was selected randomly out of a total of 6061, taking into consideration the school and age of the children. To validate the developed Meal IQ, it was necessary to have weighed food records. Based on digital images of the lunches brought from home, an identical double portion of the meal was produced and the weight of the lunches' various food items was recorded. In the intervention schools, thirty-one different lunches provided by the schools were served. Recipes and product specifications for these lunches were collected. Two of each of the school meals were bought and the food items were weighed and registered in order to obtain the weighed food records. The data were collected during August–December 2008 and February–April 2009.

To increase the number of lunches provided by schools and thereby ensure greater representativeness, another thirty-two provided school meals were included in the study sample. These meals were collected in another Danish study in eighteen public schools, representative for Danish schools in terms of degree of urbanization and size (numbers of pupils)[17]. Weights of the food items in the lunches provided at the schools were recorded and recipes and product specifications were collected. These data were collected during November 2007–April 2008.

In total, the study sample consisted of weighed food records for 254 school lunches: 191 lunches brought from home and sixty-three lunches provided by schools.

Development of the Meal Index of dietary Quality

Overall model selection

The Meal Index of dietary Quality (Meal IQ) scoring system was developed to provide a simple measure of dietary quality of school lunches for children aged 7–13 years. The steps in the development of the Meal IQ were inspired by a nutrient profiling approach[18] and included: selection of variables; selection of measures for assessing the variables; definition of scoring systems and thresholds; and validation of the Meal IQ (Fig. 1).

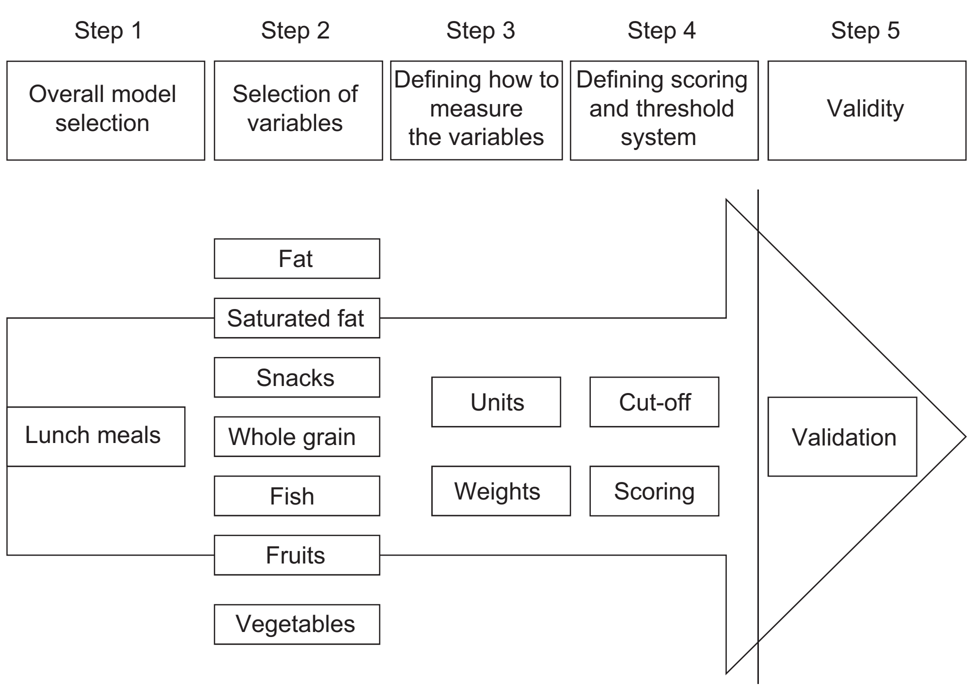

Fig. 1 Steps in the development and validation of the Meal Index of dietary Quality (Meal IQ). Modified from Verhagen and van den Berg[18]

Selection of variables

The selection of variables was based on the dietary issues that are particularly relevant to the lunches and general food intake of children aged 7–13 and also on knowledge of the association between nutrients/food groups and chronic diseases.

Data from the Danish National Survey of Dietary Habits and Physical Activity revealed that to meet the official nutrition recommendations[19] and the dietary guidelines[20], Danish children should eat less fat, especially saturated fat, and less added sugar. Furthermore, children should increase their intakes of fruits, vegetables, whole grain and fish[21–23]. These considerations led to a Meal IQ consisting of seven components, which reflect the following nutrients and food groups: fat, saturated fat, sweet snacks as a proxy for added sugar, whole grain, fish, fruits and vegetables.

Measurement of variables

The Meal IQ components, i.e. fruit, vegetables and fish, were estimated in grams. To estimate total fat, saturated fat, whole grain/potatoes and snack products in the lunch meals, unit sizes were defined in terms of household measures such as slices, cups and pieces[14]. For validation purposes, weights in grams were assigned to each of the units; and from the weighed food records, the different number of units could be estimated.

In the development of the Meal IQ, nutrition criteria such as balance, moderation and adequacy were used to ensure the recommended macronutrient distribution within the meal. As a measure of the relative content of fat in the meal, fat units were combined with the number of starchy food units to ensure the right balance. The number of fat units was subtracted from the number of starchy food units. A fat unit was defined as 5 g of fat. This corresponds to approximately 50 g of a medium-fat product with about 10 % fat (e.g. chicken with skin, meat used for skewers); 20 g of a high-fat product (e.g. liver pâté, sausage, feta cheese: approximately 25 % fat); 10 g of a very-high-fat product (e.g. bacon, pepperoni, regular vinegar/oil salad dressing: approximately 50 % fat); or 5 g of solid fats and oils (e.g. butter, oil, mayonnaise: 80 % or more fat). Low-fat products (e.g. lean ham, cottage cheese: 5 % fat or less) do not contribute to the fat unit accounts. Furthermore, fish and plain nuts were not counted as fat units, regardless of fat content, as these foods are considered part of a healthy diet. A starchy unit corresponded to 50 g of bread, 75 g of pasta or rice, 150 g of potatoes, 300 g of vegetables, 200 g of fruits and 35 g of dried fruits, which corresponded to an energy content of about 400–500 kJ (about 25 g of starch per unit).

If the fat units were animal-based they were counted and used as an approximation of the content of saturated fat in the meal. Whole grain and potatoes were combined in the same score, since potatoes (cooked, baked or mashed) are a common accompaniment to hot meals as an alternative to rice or pasta, and it is recommended to eat potatoes several times weekly[20]. The number of starchy food units, which consist of a wholegrain product or potatoes, was counted to reflect the content of healthy starch units (whole grain) in the meal. A wholegrain product was defined as containing $\geq$51 % DM[23] (e.g. rye bread, wholemeal pasta and brown rice). Snack products were used as a proxy for the content of added sugar. A snack product was defined as having a nutrient content beyond the following limits: fat $>$10 g/100 g and/or saturated fat $>$4 g/100 g and/or added sugar $>$10 g/100 g[24]. The starchy units in snack products often consist of more added sugar. The starchy units in snack products were counted separately, and this assessment was relevant for the differentiation of the score for this component of the Meal IQ. The contribution of fat units and saturated fat units from the snack products was also counted, and was added to the total fat units.

To make the assessment of fat units, saturated fat units and starchy units from snack products as simple as possible, lists were made to support the process. The lists for assessment of fat units contained the most common fat-containing products, with information on the fat content per 100 g of the product and the quality of the fat; and the list of the most used snack products contained information about the contents of starch and fat and fat quality of one snack product or 100 g of the product.

Defining scoring systems and thresholds

Each of the seven components of the Meal IQ was scored from 0 (lack of compliance) to 4 (full compliance) with intermediate scores reflecting level of attainment towards dietary recommendations[19,20], but intake level in the population was also taken into consideration, especially when cut-offs for the components, which build on units, were defined. However, for snack products, the score was assessed somewhat differently. If no snack product was present in the meal, 4 points were given. If the meal contained a snack product, then the score 0 or 2 could be given, depending on the contribution of starchy units it contained. If the contribution of starchy units was $\geq$0·5 units, the score would be 0, but if the content of starchy units was $<$0·5 units then the score of 2 was given. The value 0·5 units was used to define the cut-off because it represents a relatively high contribution of starch from the snack product, about 10 % of the energy content of the meal. If most of the starch is added sugar, the content of added sugar meets the maximum level, according to the official nutrition recommendation[19]. The total score for the Meal IQ ranged from 0 to 28. The construction and criteria for scoring each component are listed in Table 1.

Validation of the Meal IQ

The Meal IQ was tested on 254 calculated meals (191 lunches brought from home and sixty-three lunches provided by schools) for its ability to assess dietary quality.

Table 1 The Meal Index of dietary Quality (Meal IQ) scoring criteria for each of the seven components

	0 point	1 point	2 points	3 points	4 points
1. Total fat (units)	Starch − fat ≤ −1	−1 < Starch − fat < −0·25	−0·25 ≤ Starch − fat ≤ 0·25	0·25 < Starch − fat ≤ 1	Starch − fat > 1
2. Saturated fat (units)	SFA > 3	3 ≤ SFA < 2	2 ≤ SFA<1	1 ≤ SFA < 0	SFA = 0
3. Whole grain and potatoes (units)*	Whole grain = 0	0<Whole grain ≤ 0·5	0·5<Whole grain ≤ 1	1 < Whole grain ≤ 1·5	Whole grain > 1·5
4. Snack products (Yes/No) (units)†	Yes and starch units > 0		Yes and starch units = 0		No
5. Fish (g)	0	0–10	10–20	20–30	>30
6. Fruits (g)	0	0–17‡/0–25§	17–33‡/25–50§	33–50‡/50–75§	≥50‡/≥75§
7. Vegetables (g)	0	0–17‡/0–25§	17–33‡/25–50§	33–50‡/50–75§	≥50‡/≥75§

*Wholegrain products have a content of whole grain ≥51 % of DM[22].
†If no snack product is present in the meal, 4 points is achieved. If the meal contains a snack product, then the score 0 or 2 could be given; if the contribution of starchy units is ≥0·5 units the score would be 0, but if the amount of the snack product is so limited that the contribution of starchy units is <0·5 units then the score of 2 is given. A snack product is defined as having a nutrient content beyond the following limits: fat >10 g/100 g and/or saturated fat >4 g/100 g and/or added sugar >10 g/100 g[23].
‡Limits for children up to 11 years of age.
§Limits for children from 11 years.

The nutrient content of the meals was calculated from the weighed food records of the meals and the recipes and product specifications. The nutrient calculations were conducted using the computer program GIES (General Intake Estimation System; National Food Institute, Søborg, Denmark)[25]. First, the single components in the Meal IQ were tested to examine if the components correlated with the nutrient concerned. Then, the Meal IQ score was estimated from the weighed food record of the lunches and validated against the calculated nutrient content of these meals.

Statistical analysis

To investigate if the selected components in the Meal IQ reflected the nutrients of concern, correlation coefficients between the estimated components and the objective measures were assessed. Because the data on dietary intake were not normally distributed, Spearman's correlation coefficient was used[26]. The estimated components were classified into quartiles. Gross misclassification was defined as classification in the opposite quartile observed in the highest and lowest quartile. Correlations between the Meal IQ score and the calculations of the nutrient content were assessed. The sample was divided into four categories according to the total Meal IQ score; and mean values of energy and nutrient content of the meals were compared by ANOVA, after testing for equality of variances, or using the Kruskal–Wallis test[27,28]. Bonferroni correction was used to account for increase in type I error due to multiple comparisons[29]. Linear trends across the categories were tested by modelling the score as a continuous variable in the model and testing for model reduction[27].

All reported P values were based on two-sided hypotheses and compared with a significance level of 5 %. Statistical analyses were carried out using the SAS statistical software package version 9·2 (SAS Institute Inc., Cary, NC, USA).

Results

Correlation between the Meal IQ components and calculated nutrient content in the school lunches

Each of the components not measured in grams (total fat, saturated fat, whole grain/potatoes and snack products) was estimated from the weighed food records and validated against the relevant calculated nutrient content (Table 2). The component estimating fat content was highly correlated to the percentage of energy from fat ($r = -0·77$). Numbers of saturated fat units were correlated to the percentage energy from saturated fat ($r = 0·76$). The number of whole grain units was correlated to dietary fibre ($r = 0·56$); and the snack component was correlated to added sugar in the meals ($r = 0·57$).

The proportion of meals which were classified into the same or adjacent quartiles from the measured component

Table 2 Correlations between the calculated nutrient content of the meal components and the nutrient components of the Meal Index of dietary Quality (Meal IQ; *n* 254)

Component		Correlation	
Calculated from weights of ingredients in the meals	Estimated values	Spearman correlation coefficient	*P* value
Fat (%E)	Starch units – fat units	−0·77	<0·0001
Saturated fat (%E)	Saturated fat units	0·76	<0·0001
Fibre (g)	Whole grain and potatoes units	0·56	<0·0001
Added sugar (%E)	Snack product score	0·57	<0·0001

%E, percentage of food energy.

Table 3 Correlations between energy and nutrient content of the meals and the total score of the Meal Index of dietary Quality (Meal IQ; *n* 254)

	Meal IQ score	
	Correlation	
	Spearman's correlation coefficient*	*P* value
Energy (kJ)	0·04	0·4844
Energy density (kJ/100 g)	−0·61	<0·0001
Fat (%E)	−0·58	<0·0001
Saturated fat (%E)	−0·63	<0·0001
Carbohydrate (%E)	0·52	<0·0001
Added sugar (%E)	−0·22	<0·0001
Fibre (g/MJ)	0·54	<0·0001
Vitamin A (μg RE)	0·13	0·0342
Vitamin D (μg)	−0·13	0·0447
Vitamin E (mg)	0·32	<0·0001
Vitamin K (mg)	0·49	<0·0001
Vitamin B_6 (mg)	0·30	<0·0001
Folic acid (μg)	0·38	<0·0001
Vitamin C (mg)	0·47	<0·0001
Ca (mg)	0·09	0·1174
Fe (mg)	0·19	0·0029
Fruits (g)	0·50	<0·0001
Vegetables (g)	0·48	<0·0001
Fish (g)	0·36	<0·0001

%E, percentage of food energy; RE, retinol equivalents.
*Spearman's correlation coefficient analyses are made using the 28-classed score.

and the nutrient of concern ranged from 91 % (whole grain units *v.* fibre) to 98 % (starch units in snack product *v.* added sugar). Gross misclassification was found in one of the 254 cases for the components measuring added sugar, saturated fat and total fat; and for the whole grain score correlated with fibre, misclassification was found in 2 % of the meals.

Correlation between the Meal IQ score and nutrient content

The results presented in Table 3 are based on comparisons of the assessed Meal IQ score from the weighed food records of the lunches brought from home or provided by the school. A higher Meal IQ score was significantly associated with lower intakes of total and saturated fat and sugar and with higher intakes of fibre, fish, fruits, vegetables and various vitamins and minerals. The Spearman's correlation coefficients between the score for Meal IQ and the nutrient content of the nutrient-calculated meals varied between dietary components and were highest for energy density ($r = -0{\cdot}61$) and lowest for energy ($r = 0{\cdot}04$) where no association was measured. The Spearman's correlation coefficients were calculated separately for the lunches brought from home and the lunches provided by the schools in order to examine if the results were similar. The separate analyses showed the same tendencies as the combined analysis of the lunches except for the association between the Meal IQ score and the energy density in the lunches provided by the school (results not shown). The correlation was not as strong ($r = -0{\cdot}13$) as seen in the lunches brought from home ($r = -0{\cdot}73$).

Table 4 illustrates the *P* values for trend across the Meal IQ categories and the *P* values for differences between the categories. The linear trend was highly significant for the percentage of energy from fat and saturated fat, fibre, vitamin E, vitamin K, vitamin B_6, folic acid, vitamin C, fruits and vegetables. There was also a trend for vitamin A ($P = 0{\cdot}0274$). The result of the analysis for trend showed no significance across the Meal IQ score for energy, energy density, percentage of energy from carbohydrate and added sugar, Ca, Fe and fish. The *P* values for the ANOVA showed a significant difference between the score categories for all the nutrient and food groups except energy and vitamin A, and after Bonferroni correction, there was no difference between the categories for Ca either.

Discussion

The results obtained in the present study indicate that the Meal IQ is a valid and useful tool for providing information on the dietary quality of school lunches brought from home or provided by the school, and thus a useful evaluation tool for school food programmes. The Meal IQ score is a good measure of dietary quality, as higher values of the score are strongly associated not only with the nutrient and food groups included in the index, but also with selected nutrients.

We found a linear trend across the Meal IQ categories for percentage of energy from fat and saturated fat, fibre, vitamin A, vitamin E, vitamin K, vitamin B_6, folic acid,

Table 4 Energy and nutrient contents of the meals by categories according to the total score of the Meal Index of dietary Quality (Meal IQ; *n* 254)

	Meal IQ score									
	0–7 points (*n* 26)		8–13 points (*n* 102)		14–19 points (*n* 105)		19–28 points (*n* 21)		*P* value for ANOVA or Kruskall–Wallis test	*P* value for trend
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Energy (kJ)	1549	631	1350	563	1358	568	1710	570	0·0539	NS
Energy density (kJ/100 g)	1032[a]	201	818[b]	256	595[c]	180	552[c]	121	<0·0001	NS
Fat (%E)	39·8[a]	6·53	33·7[b]	10·1	24·6[c]	9·17	22·1[c]	6·92	<0·0001	<0·0001
Saturated fat (%E)	15·8[a]	5·04	11·5[b]	4·63	7·00[c]	3·96	5·30[c]	3·00	<0·0001	<0·0001
Carbohydrate (%E)	46·7[a]	7·68	49·9[a]	11·4	60·3[b]	10·5	61·5[b]	9·38	<0·0001	NS
Added sugar (%E)	3·79[a]	5·69	1·06[b]	2·12	0·49[b]	1·41	0·08[b]	0·14	0·0009	NS
Fibre (g/MJ)	3·23[a]	1·56	4·26[a]	1·75	5·75[b]	1·98	6·41[b]	1·42	<0·0001	<0·001
Vitamin A (μg RE)	225	391	262	291	322	325	421	352	0·0966	0·0274
Vitamin D (μg)	0·23[a]	0·21	0·22[a]	0·36	0·19[a]	0·44	0·83[b]	1·26	0·0001	NS
Vitamin E (mg)	0·88[a]	0·61	1·19[a]	1·06	1·42[ab]	1·04	1·93[b]	1·01	<0·0001	<0·0001
Vitamin K (mg)	2·36[a]	3·85	10·3[ab]	15·9	14·1[b]	14·0	24·6[c]	13·1	<0·0001	<0·0001
Vitamin B_6 (mg)	0·19[a]	0·12	0·24[ab]	0·15	0·27[b]	0·13	0·39[c]	0·14	<0·0001	<0·0001
Folic acid (μg)	33·1[a]	26·0	54·1[b]	31·4	68·6[c]	37·3	90·0[d]	29·4	<0·0001	<0·0001
Vitamin C (mg)	9·27[a]	6·38	15·5[a]	17·8	25·4[b]	21·7	26·5[b]	16·4	<0·0001	<0·0001
Ca (mg)	128[a]	151	83·5[a]	82·6	83·4[a]	62·7	122[a]	110	0·0234	NS
Fe (mg)	2·15[a]	1·55	1·95[a]	0·95	2·16[a]	1·12	3·36[b]	2·15	0·0012	NS
Fruits (g)	0·58[a]	2·94	8·03[a]	28·7	41·5[b]	67·8	52·6[b]	55·2	<0·0001	<0·0001
Vegetables (g)*	5·00[a]	11·3	41·3[b]	50·1	64·6[c]	48·9	90·6[c]	42·1	<0·0001	<0·0001
Fish (g)	1·08[a]	5·49	0·90[a]	6·06	4·40[a]	14·0	21·8[b]	28·2	<0·0001	NS

%E, percentage of food energy; RE, retinol equivalents.
[a,b,c,d]Mean values within a row with unlike superscript letters were significantly different after Bonferroni correction for multiple comparisons ($P < 0·05$).
*Excluding potatoes.

vitamin C, fruits and vegetables. But we did not find a trend for all nutrient and food groups. The missing trend for sugar and fish might be explained by the fact that a high content of added sugar was found only in the meals with low scores, and fish was mainly present in the lunches with high Meal IQ scores. This was also the result of the ANOVA after Bonferroni correction for multiple comparisons, where a significant difference was found between the content of added sugar in the category for meals with the lowest Meal IQ score and the other three categories. The same picture was seen when analysing the content of fish in the four categories, where the meals with the highest Meal IQ score had a significantly higher amount of fish compared with the other three categories. This could also explain the absent trend for vitamin D, as this micronutrient is highly present in fish. The content of Ca in the meals did not show either a trend or any differences between the categories. The reason for this might be that all types of meals contain cheese, for example, and the one scoring lowest also contains spread and cheese snacks which all contribute to the Ca content; and the meals with high scores also contain Ca from vegetables. The lack of trend for Fe is due to the content of Fe in meat, which is present in most of the lunches, but the amount of fat in the meat may vary. Fortification could have had an influence on the results of trends across the categories for micronutrients, but in Denmark fortification is not common. The non-significant trend across categories for energy density was unexpected, but it may be due to a wide variation in energy content. The ANOVA showed a highly significant P value ($P < 0{\cdot}0001$) for the general difference among the categories for energy density. Pair-wise differences between the categories after Bonferroni correction showed a significant difference between all the groups ($P < 0{\cdot}05$) except for the last two. Lassen *et al.*[14] did not do a trend analyses when analysing the energy density across categories for the score of the SHMI, but they found a significant difference between categories in the total score of the SHMI for energy density using ANOVA; after Bonferroni correction, however, there was no difference between the two middle categories.

Because nutrient intake is positively correlated with energy intake, a diet quality index could overrate high-energy diets, especially if nutrient adequacy is weighted more heavily than moderation[30]. Several indices show an association between the score and total energy intake[4,8,10]. In the Meal IQ, both nutrient adequacy and moderation are represented among the chosen components. We did not find any correlation between the Meal IQ score and total energy intake. This should be noted as an advantage, because the Meal IQ can assess diet quality independently of diet quantity. Another methodological issue concerning dietary indices is how to combine the different components into one measure[2]. Often the components incorporated in the indices are considered equally important. In the Meal IQ, we attempted to focus more on fruits and vegetables and fat by dividing fruits and vegetables into two components, and also having separate components for total fat and saturated fat. Another issue is the scoring of each component (binary, proportional or other)[2,31]. In the Meal IQ, we have mainly used a proportional approach on the assumption that the difference from 0 to 1 is the same as from 1 to 2. This may not be completely true. If total fat goes from 25 to 20 % of energy, the effect is not the same as from 40 to 35 % of energy. Future study could do further work on differentiations in the single component scores in the Meal IQ, and also on different strategies for scoring of the variables. For instance, the correlation with regard to total fat may be better described by a U-shaped relationship than by the proportional approach.

Not all aspects of nutritional recommendations are implemented in the Meal IQ. Beverages were not included as a component in the Meal IQ, because the relationship between energy density and macronutrient content in beverages is more complex than in individual foods or meals[32]. Besides the focus was on developing a tool for assessing differences between lunches brought from home and lunches provided by the schools, and since beverages are not part of the school food programme in Denmark, this component was not included. Beverages may contribute significantly to total energy intake, but data from the Danish National Survey of Dietary Habits and Physical Activity show that more than half of school-aged children (7–13 years) drink water or low-fat milk for lunch at school[22]. Incorporating beverages as a component in the Meal IQ could be relevant in future studies. In addition, the index does not deal with salt content, which should be developed and tested for future extension of the Meal IQ. Further research is needed to determine the dietary elements that are most related to health among children/youth.

The Meal IQ focuses on the overall dietary quality of a meal. The official recommendations are valid for the average intake for a longer period, at least a week, since the dietary composition may vary from meal to meal and from day to day[19]. It is therefore a challenge to establish dietary guidelines for a single meal, but this was done by defining cut-off points for the Meal IQ components based on the official recommendations and dietary guidelines. When defining the official recommendations, the current food consumption patterns were taken into account. This was also done when defining the Meal IQ scoring system for whole grain: if the starting point was that children should receive 25 % of their daily energy needs from the lunch they eat at school, then the upper cut-off for whole grain should be about 25 % of the recommended intake. But for whole grain, the limit was set above 25 % of the recommended daily intake because Danish children eat rye bread at lunch[23], which is an important source of whole grain; therefore, it is likely that the lunch would provide more whole grain. From this point of view, it would be appropriate to develop specific indices for the different types of meals and for specific target groups.

A limitation of using the Meal IQ is the need for recipes and product specifications, especially when assessing the Meal IQ components for hot meals, for which it can be difficult to assess the content of e.g. fat and the amounts of vegetables. It is relatively easy to get information on the lunches provided by the schools, because recipes are available and the meals are often standardized.

One of the advantages of the Meal IQ is that the score is easily obtained through a simple evaluation process. The seven components incorporated in the Meal IQ can be determined from a weighed food record. There is no need for calculations of the nutrient content, which would make the calculation of the total score more complex and labour-intensive as in the Healthy Eating Index (HEI)[4] and the RC-DQI[12], among others.

In conclusion, the new Meal IQ is an easily applied evaluation tool for assessing the dietary quality of lunches provided by schools or brought from home. The method is valid, simple, flexible and sensitive. The Meal IQ is a tool that can be used by health professionals at various levels to evaluate health promotion interventions in schools.

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Paper III

Effect of implementing school meals compared with packed lunches on quality of dietary intake among children aged 7-13 years.

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Abstract

Objective: The aim of the present study was to evaluate the effect of implementing a school food programme on the dietary quality of lunches consumed by school children aged 7-13 years compared with packed lunches brought from home. A secondary objective was to investigate if a possible effect would differ between the youngest school children and the older.

Design: A quasi-experimental study design with 4 intervention schools and 4 matched control schools was conducted. Data on packed lunches were collected at baseline. At 1st follow-up the children in the intervention schools were offered free school meals and at the 2nd follow-up the school meals were paid. The control group had packed lunches at all measurements. A standardized digital photographic method combined with a Meal Index of dietary Quality (Meal IQ) was used for dietary assessment. Multilevel modeling was employed for data analyses.

Setting: 8 public schools from all over Denmark.

Subjects: 984 school children.

Results: The change in quality of dietary intake was improved when free school meals were offered (*P*=0.004), if the school meals were paid the use was limited and no difference in change in dietary quality was found (*P*=0.343). The school food programme had no different effect according to age (*P*=0.083).

Conclusions: Offering a free school meal had a positive effect on change in dietary quality of the lunches consumed by school children aged 7-13 years. No effect was measured when the school meals were not provided for free. The dietary effect did not depend on age.

Keywords: school-based intervention, dietary intervention, nutrition programme, multilevel analysis

Introduction

Healthy dietary habits during childhood promote optimal health, growth and cognitive development of the child, and may contribute to the prevention of chronic diseases in later life[1,2]. Some evidence exists, that nutrition behaviors track from childhood into adulthood[3,4], and thus it's important to establish healthy dietary habits early in life.

The dietary habits of children in Denmark[5], as well as for children in other Western countries call for improvement[6]. Data from the recent Danish National Survey of Dietary Habits and Physical Activity revealed that to meet the official nutrition recommendations[7] and the food-based dietary guidelines[8] Danish children should eat less fat and especially saturated fat and less added sugar and increase their intake of fruits, vegetables, whole grain and fish[5,9,10]. Thus, there is a need for strategies to promote and provide healthy dietary habits among children. The school has been recognized as an important setting for such a health promotion strategy, because health related behaviors can be influenced, especially healthy eating habits[11-14]. The school reaches all school-aged children of diverse ethnic and socio-economic groups and offers an environment that is accessible to all on equal terms.

In Denmark 85% of children in the age of 7-14 years eat a packed lunch brought from home during school hours[10]. Studies in Denmark[10,15] as well as in other countries[16-19] have shown that the dietary quality of packed lunches do not always meet the dietary guidelines. Several cross-sectional studies have compared the nutritional quality of packed lunches and school meals provided by the schools and concluded that the children who eat the school meals generally have a healthier lunch compared to children who eat a packed lunch[20-26]. However, no intervention studies have evaluated this issue specifically. A number of school-based intervention studies have been published. The interventions vary to a great extent in terms of intervention (nutrition education, environmental interventions or multicomponent interventions), duration of the intervention, outcome measures and significance of the results[27-29]. No studies where substituting the whole lunch meal have been published and no intervention study investigating the effect of school meals instead of packed lunches on the dietary quality of the lunch consumed.

In a recent systematic review Brown and Summerbell found that some interventions appeared to vary in effectiveness according to e.g. age of the children[29]. Furthermore a Danish study showed that students had different attitudes toward school food programmes. The youngest children, representing the 3rd grade seemed to appreciate the packed lunches brought from home but children from the 6th grade were happier with the school meals[30]. The prevalence of children who bring their lunch from home decreases with age. The youngest school children are comfortable with their packed lunches, but the starting youth culture influences the status of the packed lunch among the older school children[31], thus it is possible that the effect of a school food programme could depend on age of the children.

The aim of the present study was to evaluate the effect of implementing a school food programme on the dietary quality of lunches consumed by school children aged 7-13 years compared with packed lunches brought from home. A secondary objective was to investigate if a possible effect would differ between the youngest school children (2nd-3rd grades) and the older (5th-6th grades).

Methods

Study sample

We conducted a quasi-experimental pre- and post-intervention design. In 2008, 38 schools received funds from the Danish Food Industry Agency to implement a school food programme, with a period of two months where the school meals were for free followed by a period where the students could buy the school meals. To evaluate the dietary effect of the school food programmes 4 intervention schools of the 38 schools were selected, taking into account representation of different geographic locations. Four control schools were selected among schools without any school food programme and matched with the 4 intervention schools with respect to municipality, size (number of children) and families' social background.

Power calculations using an α level of 0·05 and a β level of 0·8 estimated that 50 children were needed to detect a difference of 2·29 g saturated fat intake, estimating the intra-class correlation to be 0·02. To examine if a possible nutritional effect of the school food programme was different between students from the 2nd-3rd grades and 5th-6th grades approximately 50 students in each age group on each of the 8 participating schools were selected.

In total 984 children were invited to the study, 493 school children from the 2nd and 3rd grades and 491 students from the 5th and 6th grades. For flow of schools, participants and number of meals see Figure 1.

Written information on the study was given to the teachers and the parents. If the parents had further questions they were able to call a project manager.

The study was approved by the Danish Data Protection Agency.

Intervention - procedure for data collection

At baseline (T1) data on packed lunches were collected in both intervention and control schools. At 1st follow-up (T2) the control schools were still having packed lunches brought from home, and the intervention schools were offered free school meals. At 2nd follow-up (T3) the controls had packed lunch and at the intervention schools the school meals were no longer for free, so the school children would either have paid school meals or packed lunches (Figure 2). The data were collected successively on the 8 schools. One or two weeks after data were collected at an intervention school collection of data took place at the matched control school. Baseline data were collected in the weeks before the intervention period began. The 1st follow-up was 8 weeks after baseline and 2nd follow-up was 6 month after baseline.

Collection of data covered 3 consecutive days during a week to cover the variability of the lunches over a week.

A validated standardized digital photographic method was used to collect dietary data on the packed lunches or the school meals[32]. At the beginning of the lunch break, the children were asked to place their lunch meals on a plate distributed to them, and all meals were photographed. Where it was difficult to determine what a sandwich contained we asked the child to open the sandwich for viewing. At the end of the lunch break, the plates were again photographed with or without leftovers. In addition, for non-visible food items, the participants were asked questions if the research staff assessed that it would be difficult to see on the digital image. The research staff attended a training session on the use of the digital photographic method before the data were collected.

On the 4 intervention schools 31 different lunches provided by the schools were served at 1st and 2nd follow-up. Recipes and product specifications for lunches provided by the schools were collected. Two of each school meals were bought and the weights of the food items registered. The data on the packed lunches and the school meals were collected during August-December 2008 and February-April 2009.

Assessment of quality of dietary intake

The dietary quality of the lunches was assessed using a validated Meal Index of dietary quality (Meal IQ), which is a tool we developed for the purpose. The Meal IQ consists of 7 components; total fat, saturated fat, whole grain, snack products, fruit, vegetables and fish, selected with the aim to assess the overall dietary quality of the lunches. The total score for the Meal IQ ranged from 0 to 28. The development and validation of the Meal IQ is reported elsewhere[33].

A database was developed in Microsoft Excel for the dietary assessment of the digital images in order to make the necessary notes on the dietary components in the Meal IQ while watching the digital image. If there were any doubts about the food items on the digital image decisions were made based on consensus between the two digital images analysts, if consensus was not possible the digital image was excluded from the study.

Self-report questionnaires/interviews and anthropometrics

A questionnaire was used to collect data on socio-demographic characteristic of the participating children. The students from the 2nd and 3rd grades were interviewed and the students from the 5th and 6th grades filled out the questionnaires themselves. The majority of the questions used were developed, validated and used in the project Pro Children[34]. Answers from the questionnaire were used to assess the social background of the child's family using The Danish Occupational Social Class (DOSC) measure[35].

At baseline the height and weight of the students were measured to calculate body mass index (BMI; kg/m^2). The measures were taken in light clothing and without shoes. Weight was measured to the nearest 0·1 kg using a Soehnle Verona 63749 digital person scales, height was registered to the nearest 1·0 cm using a Soehnle 5003 digital height rod.

Statistical analysis

The dietary effect of the school food programme was examined using the Meal IQ score which were measured as repeated measurements for the same group of children at baseline (T1), 1st follow-up (T2) and 2nd follow-up (T3). The analyses were conducted on the differences of the Meal IQ score compared to baseline by using the following model:

$$y = \mu_0 + b + gr + t + in + s + ge + k + t*b + t*gr + t*in + t*s + t*ge + t*k + gr*in*t$$

Where *y* is the response variable (the difference in Meal IQ score relative to baseline value), μ_0 is the intercept (over all mean), *b* is the BMI value at baseline, *gr* represent the grades (2nd-3rd grades and 5th-6th grades), *t* represent the measurement times (T2 and T3), *in* represent two groups (intervention and control), *s* represent the social status, *ge* represent the gender, *k* is the Meal IQ score at baseline, and *t*b, t*gr, t*in, t*s, t*ge, and t*k* represent the two-way interactions with the time, *t*, and *gr*in*t* the three-way interaction-term. In addition to the deterministic variables the model given above included a number of stochastic variables which took into account the clustering of children within schools and classes and the repeated measurements of the same child. Thus the following hieratical structure was included in the model:

$$SC(IN),\ C(SC*IN),\ IP(SC*C*IN)$$

Where *SC* represent the schools and is nested with intervention (*IN*), *C* represent the classes and is nested with school and intervention, and *IP* represent a personal index for each child participation in the study and is nested with school, class, and intervention.

The two-way interaction terms were included in the model to test whether the development in the mean changes in Meal IQ score were parallel over time e.g. in intervention and control schools (*t*in)*.

Contrasts were constructed from the fitted model to test the particular hypothesis: if a mean change in the quality of dietary intake was found when school children eat school meals instead of packed lunches. This was tested at the time period at 1st follow-up and 2nd follow-up. The estimated mean change values in the contrast were adjusted for others of the relevant factors in the model.

Prior of the main analyses baseline tests were conducted verify that the participating children in the selected schools and classes were not significantly different from each other according to age, sex, BMI, social background of the families, and the Meal IQ score.

$P<0{\cdot}05$ was considered statistically significant. All reported p values were based on two-sided hypotheses. Statistical analyses were carried out using the SAS statistical software package, proc mixed (version 9.2, SAS Institute Inc., Cary, NC, USA).

Results

Baseline characteristics of the children

Table 1 shows the characteristics of the participating children at baseline. No significant differences were found between the intervention group and the control group in socio-demographic variables at baseline except for ‘age’ among the youngest school children ($P<0{\cdot}0001$). This difference occurred due to more 3rd grade students in the control group. Regarding the quality of the dietary intake (expressed by the Meal IQ score) from the packed lunches brought from home there were no difference between the intervention and the control group.

Intervention effect on dietary quality of lunch consumed

Figure 1 describes the flow of the participating school children and collected meals. Because the response variable is the difference in Meal IQ score relative to baseline value only the school children participating at baseline were included in the analyses. At T2 the numbers of children is 951 and at T3 936 children are included in the analyses. In total data on 8056 lunch meals were included in the analysis, in 2431 cases we collected dietary data from a child during the three measurements we collected all 3 lunch meals, 341 times we had 2 lunch meals and in 81 cases data on one lunch meal was obtained. 146 meals were excluded because data at baseline were not obtained. Three lunches were excluded from the analyses because consensus between the analysts was not reached about the food items on the digital images.

Figure 3 illustrates the development of the changes in the dietary quality of the lunch consumed, expressed by the fitted Meal IQ values, in children in the 2^{nd}-3^{rd} grades and 5^{th}-6^{th} grades in the intervention and control schools at T1, T2 and T3.

A different development over time was seen between the intervention group and the control group illustrated by a significant interaction term *in*t* (time x intervention) (P<0·0001) (Table 2). The overall tests of differences in change between children at the intervention schools and the control schools at the time point T2 and T3 was investigated. At T2 children in the intervention schools, eating school meals provided by the school, had a significantly improved dietary quality of the lunch consumed relative to children in the control schools, having packed lunches brought from home (P=0·004). At T3, about 4 month after the intervention no significant difference between the dietary quality of lunch consumed in the intervention and control schools was found (P=0·343).

The Meal IQ score of the two age groups divided into 2^{nd}-3^{rd} grades and 5^{th}-6^{th} grades was significant different at baseline (P<0·0001). The mean Meal IQ score for the youngest and oldest age group was respectively 11·7 (SD 4·5) and 11·1 (SD 5·4). Furthermore, a significant interaction between time and grade was found (P<0.0001) (Table 2) indicating a different development in changes in dietary quality over time depending on age. The three-way interaction-term (time x intervention x grade) however, was non-significant (P=0.083) which shows that there is no different effect of the school food programme at T2 and T3 between children in the 2^{nd}-3^{rd} grades and 5^{th}-6^{th} grades. Thus the differences between age groups seen in Figure 3 are not due to accessibility of school meals.

Table 2 shows the P-values and the parameter effect estimates of the explanatory variables significantly associated with the change in dietary quality for the final model.

Some of the different effect of age is explained by the fact that more children in the 5th and 6th grades did not bring a packed lunch or skipped a meal compared to the children in the 2nd and 3rd grades. When this effect *m* (skip a meal yes/no/sometimes) was accounted for in the model as a new explanatory variable the variable *gr* (grade) was no longer significant and was taken out of the model since most of the reason for a difference between the grades was explained by this 'new' variable.

If a child does not eat a meal at all in the timetabled lunch break the Meal IQ score is 0. These observations of children not eating lunch were included in the multilevel analyses. Analyses were also done where the skipped meals were excluded. These analyses showed the same overall results, that a significant difference between the intervention and control groups was found at the time point T2 (P=0·0006) and no difference was detected at T3 (P=0·553).

Sustainability of the school food programmes

Only at two of the four intervention schools the school food programme continued beyond the period of free school meals and at one of the schools the school food programme only continued partly. At these two schools respectively 21% and 6% of the lunch meals consumed were school meals. Overall only 7% of the lunch meals collected on the intervention schools at T3 were school meals.

Discussion

The results show that the dietary quality of the lunch eaten at school was improved when school children aged 7-13 years had free school meals instead of packed lunches. When the school meals were not provided for free the use was limited and no difference in dietary effect was found between children at the intervention and control schools. Furthermore the analyses showed that there was no statistical different effect of the school food programme according to age group. Most of the reason for the different development in changes in the Meal IQ score between children in the 2nd-3rd grades and 5th-6th grades is explained by more skipped meals in the oldest age group.

The improved dietary quality when students have school meals is consistent with the results from several cross-sectional studies[19-26,36-50] including a meta-analysis, on 7 studies, where Evans *et al*. compared British school meals and packed lunches from 1990 to 2007 measuring lunchtime nutrient intake in children aged 5-11 years. The strength of a cross-sectional design is weaker than that of the intervention studies according to their ability to provide evidence for causal relationships. To our knowledge this study is the first intervention study to examine if the dietary quality of the lunch consumed was different when school children had school meals instead of packed lunches. Other school-based intervention studies have not exchanged a whole meal, but instead focused on single food groups as e.g. fruit and vegetables(51-53) or nutrients e.g. fat(54) or whole grain(55). School-based interventions are heterogeneous in terms of design, participants, intervention, outcomes and duration, making it difficult to generalize about which intervention components are most effective. Cauwenberghe *et al*.(27) conducted a review on 42 European intervention studies with the purpose to summarize the effectiveness of school-based interventions to promote a healthy diet in children (6-12 years) and adolescents (13-18 years). They concluded that in children (6-12 years) strong evidence was found of effects of multicomponent interventions on fruit and vegetable intake. The overall conclusion was that evidence was found for the effectiveness of especially multicomponent interventions promoting a healthy diet in school-aged children in European Union countries on self-reported dietary behavior. De Bourdeaudhuij *et al*.(28) reviewed the evidence of school-based interventions promoting a healthy diet together with healthy physical activity habits on behavioral determinants, healthy diets and physical activity habits, and measures of obesity in primary and secondary school children in Europe. In younger children (6-12 years) the evidence was found to be inconclusive as to multicomponent interventions have positive impact on child obesity in the European context. Overall they suggest that combining educational and environmental components that focus on both healthy diet and physical activity give better and more relevant effects.

This study attempted to influence eating behavior in school children via availability (T2) or accessibility (T3) of school meals. Nevertheless, it seems that interventions operating at several levels could be an important strategy when children's dietary habits should be improved. So it is possible that another intervention design, e.g. a multicomponent version, may have improved the sustainability of the dietary effect.

A review(29) and a cross-sectional study(30) have reported different results of school food programmes/interventions according to age. However, the differences between age groups in the present study were not due to the school food programme but could be explained by a higher prevalence of skipped meals among children in the 5th and 6th grades compared to children in the 2nd and 3rd grades. Especially at T3 the oldest children did often skip a lunch meal. Ten percent did none of the days at T3 bring or eat a lunch, for the youngest applied this 0·5%. The reason why the oldest school children did not bring a packed lunch could be due to that they already have been eating their lunch or maybe they eat after school. According to the literature the starting youth culture could also explain why the packed lunches are not so popular among children in the 5th and 6th grades[31].

In the present study the quality of the dietary intake from the lunches was no longer significantly different between the intervention and the comparison schools at the 2nd follow-up. This could be explained by the limited use of the school food programme when the school meals were no longer provided for free and thus relatively few school meals (7%) were represented on the intervention schools at this measurement. This result indicates strongly that the economic perspective of the school food programme is important for the general dietary effects and the sustainability of school food programmes.

In this study we measured the food eaten in the timetabled lunch break. It is unsure if the overall dietary quality of the diet for the whole day is influenced by the dietary quality of the lunch or if a poor or healthy dietary intake is compensated for during the rest of the day. Two cross-sectional studies have compared packed lunches and school meals and also measured the whole day's energy and nutrient intake. One study suggested that the differences in intakes were compensated for by other foods consumed during the day, such that daily nutrient intakes were not significantly different[42] and the other study suggested that the difference according to type of meal persisted assessing the nutrient intake of the whole day[23]. This issue has to be investigated further.

A limitation of this study was the randomization procedure, where a complete randomization was not possible because the intervention schools were selected among the group of schools receiving funds form the Danish Food Industry Agency for implementing the school food programme. However, the study schools were matched with controls on key variables.

In the present study we used the multilevel analysis which is a strength while it takes into account the study design and also the structure of the data. Not all school-based studies have utilized the hierarchical structure of the data (students nested within schools and students within classes) in their statistical analysis, which might have led to biased conclusions regarding the effect of school[56,57]. We adjusted our analyses for various known or potential confounders, but we cannot exclude confounding through factors that were not considered.

It is a challenge to assess dietary intake among children. Using a validated digital photographic method overcomes the recall problems and difficulties in estimating portion sizes that exist when collecting dietary data on children, and has the positive side effect that it minimizes the burden of the respondent[32]. The used Meal IQ score, that has been shown to be a valid indicator of the overall dietary quality, was developed with the purpose to be simple, flexible with regard to the different types of meals, and it also had to be sensitive enough to measure relevant differences when children were having school meals instead of packed lunches[33]. The Meal IQ does not give information on the energy or the exact nutrient content of the meals, but as a tool for evaluation of school-based interventions or interventions in other settings it seems very suitable.

Most Danish school children bring their packed lunch from home and the lunches do not in general met the dietary recommendations[5,7,8,10]. The results of the present study suggest important national implications for school food programmes as a potential relevant health promoting strategy which may improve the quality of dietary intake at lunch. However, this requires additional research on how school food programmes can be better implemented, including knowledge about the economic perspective of this area.

In conclusion the implementation of the school food programme had a positive effect on the dietary quality of the lunches consumed by students aged 7-13 years in the period where the school meals were offered for free, but when the school meals were paid by the parents the use was limited and no effect was measured. The dietary effect of the school food programme did not differ between the children in 2nd-3rd grades and 5th-6th grades.

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Legends:

Figure 1: Flow of schools, participants and meals through study

Figure 2: Study design

Table 1: Characteristics of the school children at baseline

Table 2: Significant explanatory variables from the main analysis of effects on changes in dietary quality. The effect estimate of all parameters plus the standard error is given together with the p-value (*n*=5333)

Figure 3: Comparison of changes in Meal IQ score between school children on intervention and control schools in 2^{nd}-3^{rd} grades and 5^{th}-6^{th} grades

Figure 1: Flow of schools, participants and meals through study

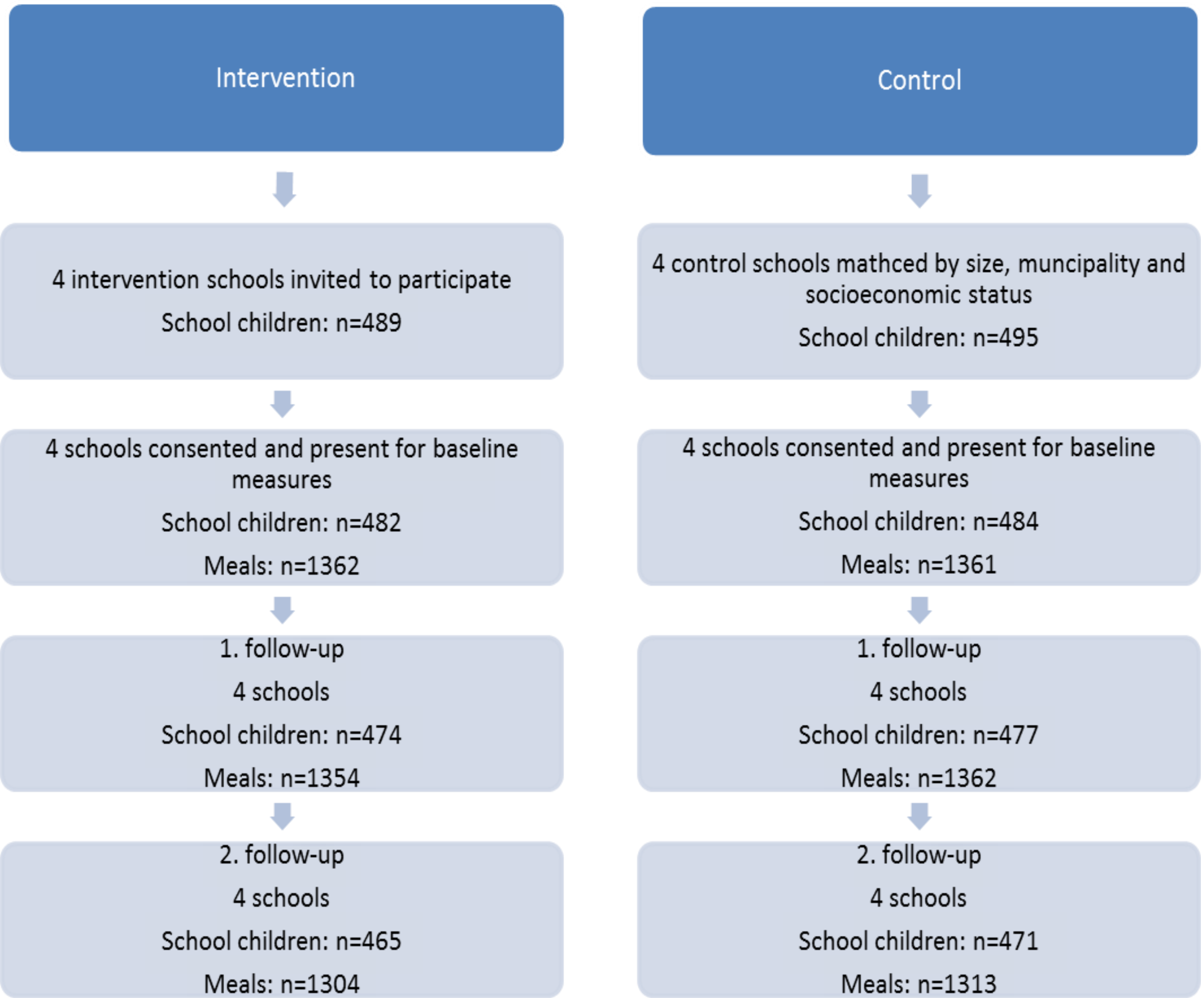

Figure 2: Study design

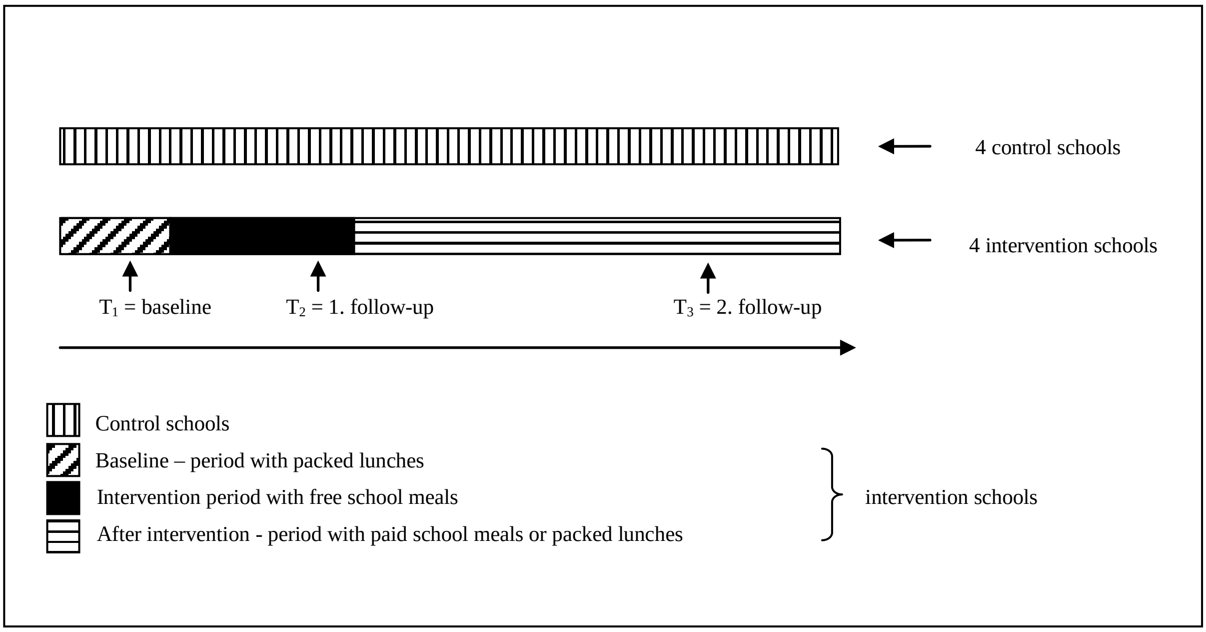

Table 1: Characteristics and quality of dietary intake (Meal Index of dietary quality (Meal IQ)) of packed lunches in the intervention and control group at baseline

Characteristics	Intervention	Control	*P*-value*
Age (years) (mean SD)	9·65 (1·65)	9·73 (1·59)	0·473
	n=446	*n*=438	
Grade (2^{nd}- 3^{rd}/5^{th}- 6^{th}) (%2^{nd}-3^{rd})	240/242 (49·8%)	246/238 (50·8%)	0·748
	n=482	*n*=484	
Gender (girls/boys) (% girls)	234/248 (48·5%)	217/267 (44·8%)	0·248
	n=482	*n*=484	
BMI (kg/m^2) (mean SD)	18·3 (2·8)	18·4 (3·2)	0·484
	n=474	*n*=473	
Social class‡			
I	29	39	0.248
II	14	14	0.991
III	165	179	0.538
IV	177	167	0.620
V	37	29	0.333
VI	40	31	0.295
VII	4	8	0.254
VIII	0	1	0.319
Missing information	16	16	0.991
Meal IQ (mean SD)	11·3 (4·8)	11·5 (5·1)	0·241
	n=1362†	*n*=1361†	

* *P*-value based on t test statistic, *P*-value for comparison of proportions are based on chi-square statistic

† Numbers of meals

‡Coded after the Danish Occupational Social Class (DOSC) [35]

Figure 3: Comparison of changes in Meal IQ score between school children on intervention and control schools in 2nd-3rd grades and 5th-6th grades

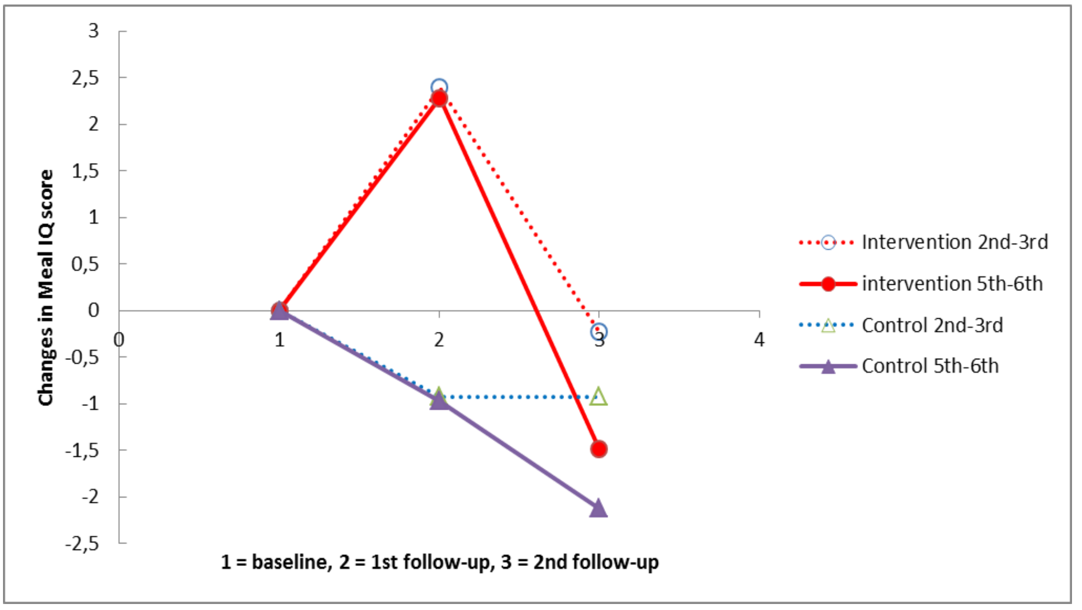

Table 2: Significant explanatory variables from the main analysis of effects on changes in dietary quality. The effect estimate of all parameters plus the standard error is given together with the *P*-value (*n*=5333).

Symbols	Effects	Estimate (SE)	*P**
μ_0	Intercept	6·99 (0·54)	<0·0001
K	Meal $IQ_{baseline}$	-0·66 (0·03)	<0·0001
In	+ intervention	3·13 (0·56)	0·016
	-intervention (control group)	0	
Gr	Grade (5^{th}-6^{th})	-0·55 (0·30)	<0·0001
	Grade (2^{nd}-3^{rd})	0	
T	Time (T_3)	-0·93 (0·48)	<0·0001
	Time (T_2)	0	
*k*t*	Meal $IQ_{baseline}$ x time (T_3)	0·08 (0·04)	0·026
	Meal $IQ_{baseline}$ x time (T_2)	0	
*in*t*	Intervention x time (T_3) (intervention group)	-2·70 (0·28)	<0·0001
	Intervention x time (T_2) (intervention group)	0	
	Intervention x time (T_3) (control group)	0	
	Intervention x time (T_2) (control group)	0	
*t*gr*	Time x grade (T_3) (5^{th}-6^{th})	-1·17(0·28)	<0·0001
	Time x grade (T_3) (2^{nd}-3^{rd})	0	
	Time x grade (T_2) (5^{th}-6^{th})	0	
	Time x grade (T_2) (2^{nd}-3^{rd})	0	

**P*-value for Type 3 tests for fixed effects

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